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AGRICULTURAL EXPERIMENT STATION

Bulletin No. 266 October, 1930

Part-Time Farming in Massachusetts

By David Rozman

In the industrial sections of Massachusetts there is a considerable number of people who work in various industries and practice agriculture on a part-time basis. This study was undertaken with the purpose of determining the place of part-time farming in Massachusetts agriculture and its effect on land utilization and food supply.

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PART-TIME FARMING IN MASSACHUSETTS

By David Rozman, Assistant Research Professor of Agricultural Economics

INTRODUCTION

There is in the State of Massachusetts a large number of people who practice agriculture on a part-time basis. Although this system of farming has been present to some extent in southern New England throughout the whole of the last century, it appears from this study that it has gained considerably in many sections of this region during the last ten or twenty years. A number of factors have been responsible for this development, especially good roads and motor transportation, which enable the operators to travel greater distances to and from their work.

The investigation of part-time farming was undertaken with the following purposes:

1. To determine the place of part-time farming in Massachusetts agriculture with special reference to the industrialized areas of the State.

2. To determine the types of part-time farming.

3. To determine the main factors responsible for the development of part-time farming.

4. To study the effect of part-time farming on land utilization.

5. To determine the importance of part-time farming as a source of food supply.

6. To determine to what extent part-time farming competes with regular agriculture in the State.

7. To analyze the economic and social consequences of part-time farming for the operators and their families.

8. To provide a more adequate basis for agricultural policies connected with problems of part-time farming.

The data for this study were obtained by means of a survey of three different areas selected with a view to obtaining a picture of part-time farming in localities with varying conditions of agriculture, industrial employment, and nationality of operators. In the northeastern section of the State the investigation was carried on in four towns situated around the city of Lowell; in the southeastern section, in the four towns between Taunton and Fall River; and in the central part, in the town of Holden in Worcester County.

Part-Time Farming Defined[1]

As conceived in this study, part-time farming represents on one hand a combined use of operator's labor in his agricultural enterprise and in some other employment, and on the other hand a combined use of land for agriculture and for other purposes, principally residential and recreational. The question naturally arises as to how much time a regular farmer will

[1] The practice of agriculture on a part-time basis in New England has been frequently referred to by many writers. It does not seem, however, that an independent study devoted specifically to this problem has ever been made. The term "part-time farming" has been introduced in this study to take the place of a number of different names ordinarily used to describe similar conditions, like "farming in the twilight zone," "one-cow farmer," "back-yard farmer," "amphibian," and so forth.

ave to spend in outside employment, or how large must be the agricultural output of an operator engaged primarily in some other occupation, before either of them can be classified as a part-time farmer. For the purposes of the present study each operator who spent two or more months a year in some outside work in addition to his agricultural activities has been given this classification. Although the limitation thus established was more or less arbitrary, it fitted fairly well the conditions existing in the areas covered by the investigation. It was large enough to exclude a number of regular farmers who occasionally performed a little outside work in their vicinity, and on the other hand it made it possible to take account of all those operators who obtained from outside employment a substantial part of their incomes. This definition of a part-time farmer was applied in each case to the head of the family who carried on his agricultural activities himself or with the help of his family, or with some occasional outside help.

In the town of Holden, where a record was taken of all part-time farming enterprises, no limit was set as to the size of landholdings or the amount of agricultural output; but in the Lowell and Taunton areas, where a special group of part-time farmers was investigated, only those were included whose agricultural output amounted to at least $100.

A distinction was also made between the part-time farmer and the part-time farming enterprise. These two do not necessarily coincide. Cases were found where heads of families were devoting to their farming activities only part of their working time, but in addition to this their grown-up sons or hired men worked on the farm on a full-time basis. In those cases the operators themselves were part-time farmers, but their enterprises were regular farms and in this study were treated as regular farming enterprises. If, however, the operator himself and the members of his family were all working on the farm on a part-time basis, the enterprise was classed as part-time farming, even though occasionally some hired help was used.

The retired people who lived on small landholdings, obtaining from farming only a part of their income and depending for their living largely on receipts from some other source, were also considered in this study as engaged in part-time farming.

Regular and Seasonal Part-Time Farmers

On the basis of the general adjustment of their working time, part-time farmers were found to be of two distinct types. One is represented by the operators who are regularly engaged in some employment outside of their landholdings and who devote to their agricultural enterprises only the time left from their daily work. The other type is found in the seasonal part-time farmers who spend all their time on the land through the farming season and hire out only after this season is over. The proportion of time any operator devoted to agriculture and other occupational pursuits varied considerably in both types of part-time farming, depending in each individual case upon the size of the enterprise, condition of outside employment, and amount of help supplied by the operator's family. Specialization in the growing of vegetables, which was practiced by a number of operators in Taunton area, was found to be well adapted to seasonal part-time farming. On the other hand, the regular part-time farmers specialized largely in small dairy and poultry enterprises, where

the working time on the farm is distributed more or less uniformly throughout the year.

Distinction on the Basis of Occupation

Another distinction between the operators was made on the basis of the nature of their outside employment. The first group, which is the most important numerically, includes skilled and unskilled industrial laborers, artisans, farm laborers and other manual laborers. In the second group are office workers and business and professional men. The importance of distinction between these two groups lies in the fact that while the first group is engaged in farming largely because of economic considerations, the members of the second often practice a little farming for its other advantages, the economic considerations playing only a secondary part.

Proportion of Part-Time Farmers Previously Engaged in Regular Farming

In the areas covered by the investigation, part-time farming developed almost exclusively as a result of the settling on the land of persons from industrial and other employments. Of the total number of operators interviewed in Lowell and Taunton areas, only seven were regular farmers before they began to practice agriculture on a part-time basis. This figure, together with the fact that the majority of operators were employed outside of their own towns, throws considerable light on the difference between part-time farming at present and part-time farming in the last century or earlier as it is described in historical studies of New England agriculture.

In the past, part-time farming flourished almost exclusively when some employment was available within the community, largely in the village mills. It was also based on a self-sufficient agriculture, where many manufacturing processes were performed on the farm.[2] In these early cases the operators were primarily farmers or children of farmers. The present part-time farmers in the industrialized areas come largely from the urban elements of population, for improved roads and the development of motor transportation have made it possible for city workers to settle on the land and commute to the place of their work.

RELATION OF PART-TIME TO REGULAR FARMING—TOWN OF HOLDEN

Varying conditions of agriculture and industry between the different sections of Massachusetts, as well as within each section, make it extremely difficult to select a community which gives a typical picture of part-time farming for the whole State. It is believed, however, that the town of Holden, with its agricultural organization and its location with regard to opportunities of industrial employment, is a fairly representative community. Data on extent of part-time farming in many industrialized towns in eastern Massachusetts would give an exaggerated notion of its importance, while a number of agricultural communities in the western part of the State would show very little of this type of agriculture.

[2] Bidwell, Percy W. Rural Economy in New England at the Beginning of the Nineteenth Century. Conn. Acad. Arts and Sci. Trans. 1916.

The main object of investigation in the town of Holden was to determine the extent of part-time farming in the community as compared with regular agriculture. Accordingly, a house-to-house survey was made in the spring of 1929, and information was obtained as to the extent of agricultural activities and occupation of operators from each household practicing some kind of agriculture, irrespective of the size of enterprise. This survey included both regular and part-time farmers.

Description of the Area

About the middle of the last century there were in operation in Holden seven industrial plants.[3] Now, however, there is only one, which is engaged in the manufacture of overcoatings and cloakings and employs between 250 and 300 operatives. The next important employer in Holden is the Boston Metropolitan Water Works, which employs from 200 to 250 laborers in the shafts situated in the Holden section. In addition, some employment is provided by work on the farms, the roads, and by miscellaneous odd jobs.

TABLE 1.—PLACE OF EMPLOYMENT OF OPERATORS AND AVERAGE DISTANCE TRAVELED.

Place of employment	HOLDEN			LOWELL AREA			TAUNTON AREA		
	Operators		Average distance	Operators		Average distance	Operators		Average distance
	No.	*%*	*Miles*	*No.*	*%*	*Miles*	*No.*	*%*	*Miles*
Same town	147	*32.4*	2.9	37	*32.2*	1.8	23	*27.4*	3.7
Nearest industrial center	296	*65.2*	5.7	59	*51.3*	3.8	40	*47.6*	5.0
Other places	11	*2.4*	11.2	19	*16.5*	11.9	21	*25.0*	3.8
Total	**454**	*100.0*		**115**	*100.0*		**84**	*100.0*	

While a considerable number of operators engaged in part-time farming find employment in the towns in which they live (Table 1), the majority must rely for outside employment on the nearest industrial center. For the operators in Holden this is the City of Worcester.

The transportation facilities in Holden include the Boston and Maine Railroad with a station at Jefferson in the northeastern section of the town. The electric car line which formerly ran from Worcester through almost the entire length of the town has discontinued its operation except for a small section adjoining Worcester. Instead, bus transportation became available from Worceser to Rutland, representing the principal means of public conveyance for the people of the town.

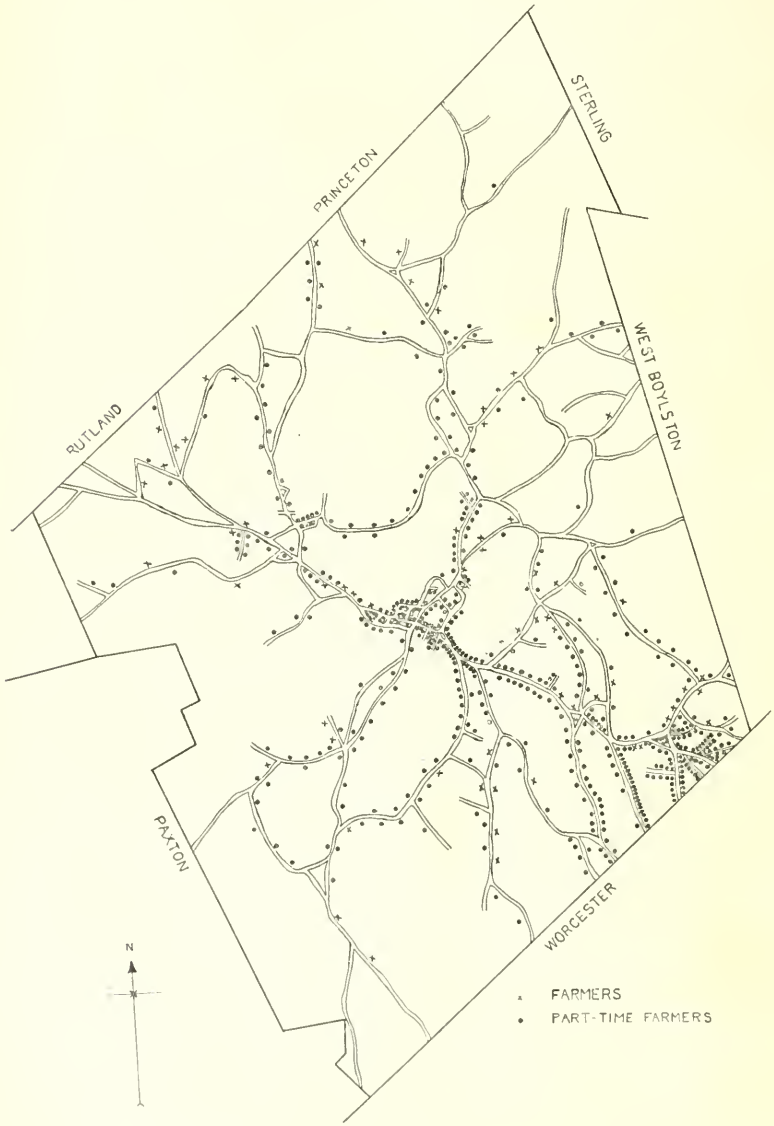
The types of soil found are characterized by a diversity typical of most glaciated agricultural regions. Most of the soils require heavy fertilization in order to produce good crops. In Holden about 50 per cent of the town area contains stony or rough land. Where the land has been cleared of stones, it is fairly good for crops. Some of the land which was formerly cultivated, however, has reverted to brush and unimproved pasture.

[3] Damon, Samuel C. The History of Holden, Massachusetts. Wallace and Ripley, Worcester, Mass. 1841.

About 15 per cent of the town area is absolutely unfit for agriculture on account of its extreme roughness and steep hills. Another 5 per cent is occupied by water, largely city reservoirs, or is low land which needs some drainage to make it suitable for agriculture. The average elevation is about 800 feet above sea level.

The location of farmers and part-time farmers in Holden is shown on the map. Most of the operators classified as laborers are employed in

Location of Farmers and Part-Time Farmers in the Town of Holden.



Worcester. The map shows a concentration of residences in the center of the town and in the southeastern section. The operators who live in the latter section find their employment right across the town line in Worcester where several large industrial plants are situated. In fact, the nearness of these industries caused the settlement of this section of the town, largely within the last five or ten years. Most of the Holden operators, however, find employment in the central industrial and business part of Worcester. The distance from the center of Holden to that section of Worcester is about seven miles; hence, those who live north of the center or at a distance from the main roads have to travel more than seven miles to their place of employment. The average distance for those employed outside of Holden is 5.7 miles. The distances traveled are shown in Chart 1.

Chart 1. Percentages of Operators Traveling Various Distances to the Place of Employment in Holden, Lowell and Taunton.

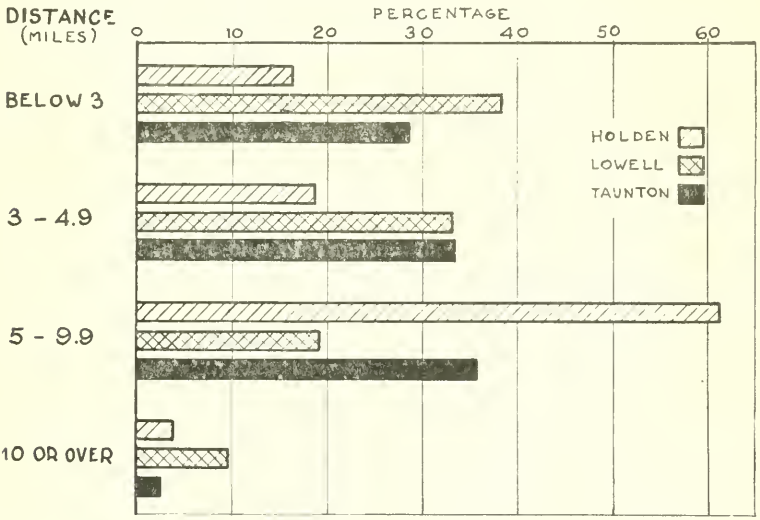


Table 2 shows the conveyances used. In all cases the automobile was the most popular means of transportation. The small number using electric cars in Holden is due to the fact that the main car line has been discontinued, and this means of transportation is now available to but a small section of the town. Of operators using automobiles, some used their own cars; some traveled with their neighbors and shared the expense. Where more than one member of a family was employed in about the same place, the automobile was used even though other means of transportation was available.

In Holden nearly three-fourths of the operators were American-born. The largest foreign-born group was Swedish, and many of those designated as Americans were of Swedish parentage. (Table 3.)

TABLE 2.—MEANS OF TRANSPORTATION USED BY OPERATORS.

	Holden		Lowell Area		Taunton Area	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Automobile	322	*75.5*	45	*39.1*	50	*59.5*
Electric car	16	*3.7*	31	*26.9*	16	*19.0*
Walking	39	*9.3*	21	*18.3*	14	*16.7*
Bus	48	*11.3*	9	*7.8*	0	*0.0*
Horse	1	*.2*	5	*4.4*	0	*0.0*
Train	0	*0.0*	4	*3.5*	0	*0.0*
Bicycle	0	*0.0*	0	*0.0*	4	*4.8*
Total	**426***	*100.0*	**115**	*100.0*	**84**	*100.0*

*The total does not include the retired people and those who had no regular place of work.

TABLE 3.—NATIONALITY OF PART-TIME FARMERS.

Nationality	Holden		Lowell Area		Taunton Area	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
American	378	*72.8*	41	*35.6*	27	*32.1*
Swedish	82	*15.8*	0	*0.0*	0	*0.0*
Polish and Lithuanian	0	*0.0*	36	*31.3*	0	*0.0*
Portuguese	0	*0.0*	0	*0.0*	36	*42.9*
Finnish	15	*2.9*	0	*0.0*	0	*0.0*
French Canadian	0	*0.0*	10	*8.7*	13	*15.5*
Italian	0	*0.0*	7	*6.1*	0	*0.0*
Others	44	*8.5*	21	*18.3*	8	*9.5*
Total	**519**	*100.0*	**115**	*100.0*	**84**	*100.0*

Extent of Part-Time Farming

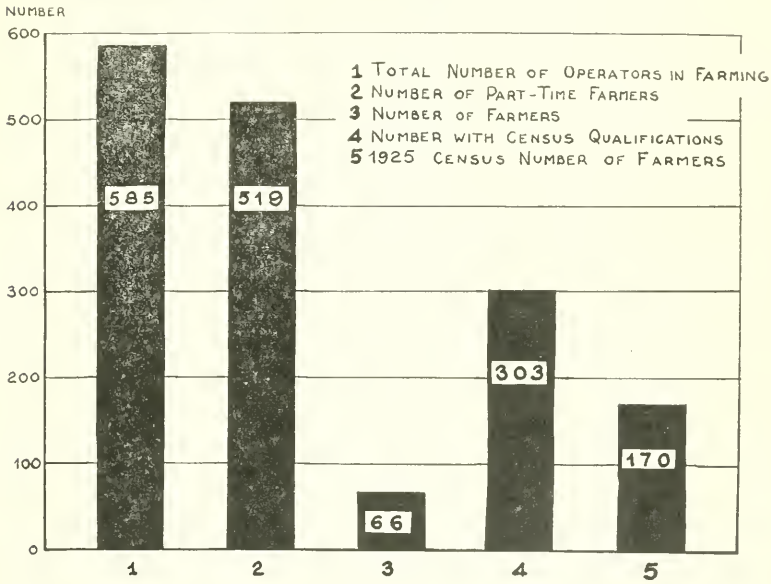
From the survey of 820 houses in Holden, it was found that 585 families living in the same number of dwellings were engaged in some farming on their landholdings. As shown in Chart 2, only 66 or a little over 11 per cent were bona fide farmers. The rest devoted only part of their time to farming, getting additional income from outside employment or some other source.

Inasmuch as part-time farming enterprises are operated mostly on a small scale, only a portion of them comes up in size or agricultural output to the minimum accepted in the definition of a farm by the United States Census. It will be noticed, furthermore, that the number of farmers listed by the United States Census of 1925 is smaller than the number coming within the census qualifications. Part of this discrepancy is probably due to changes in the agricultural structure of the town during the intervening five-year period. Another reason is probably the inherent difficulty of taking a complete count of small-scale enterprises in a census dealing primarily with regular farming enterprises.

The inclusion of all farming and part-time farming enterprises in the present survey resulted also in obtaining for the town a much larger area in farming than was recorded by the census, the figures being 10,562 acres and 7,454 acres, respectively.

The assumption that conditions in Holden reflect approximately the agricultural situation in the major part of the State would lead to the conclusion that the total land area in farming and the number of operators engaged in it are much larger in Massachusetts than reported by the census figures. On the other hand, it also becomes clear that the number of farmers listed by the census includes some operators farming on a part-time basis.

Chart 2. Number of Farmers and Part-Time Farmers in Holden.



Occupations of Operators

The occupational division of operators as demonstrated in Chart 3 indicates that the great majority (61 per cent) of part-time farmers found their outside employment as industrial laborers or artisans. Most of them derive from farming an essential share of their income, which becomes more important in time of slack employment when they tend to expand their agricultural activities. The operators represented by office workers and business and professional men were found to be less concerned with the economic advantages that might result from their farming operations.

Acreage and Production in Farming and Part-Time Farming Enterprises

The relative importance of part-time farming in the agricultural structure of Holden is well demonstrated by comparison of farm and crop acreage in farming and part-time farming enterprises, and the value of products obtained from each type of enterprise.

Chart 4 shows that land in crops and also total value of products were

Chart 3. Occupations of Operators in Holden.

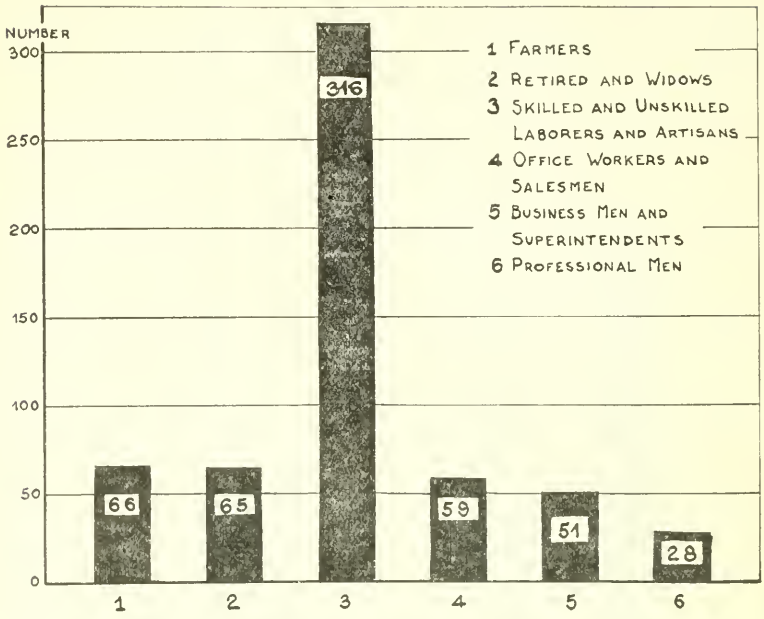
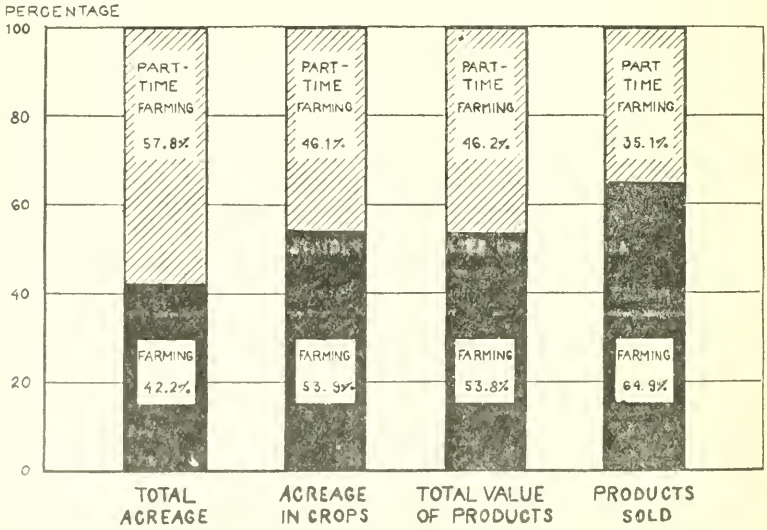


Chart 4. Percentage of Total Acreage and Value of Production in Farming and Part-Time Farming in Holden.



almost evenly divided between regular and part-time farming. Although the production in most part-time farming enterprises is intended primarily for family consumption, the proportion of products sold by them amounted to over one-third of the total value of produce offered for sale by local producers. Part-time farming enterprises, therefore, exercised a considerable influence on local prices and general marketing conditions of agricultural products.

TABLE 4.—PART-TIME FARMING ENTERPRISES CLASSIFIED BY VALUE OF OUTPUT.

Value of Output	Number	*Per cent*
Below $50	124	*23.9*
$50— 99	89	*17.1*
100— 249	137	*26.4*
250— 499	79	*15.2*
500— 999	57	*11.0*
1000 or over	33	*6.4*
Total	**519**	*100.0*

Table 4 shows the value of the products of all part-time farming enterprises. Nearly one-half had an output worth less than $100, while a number of operators produced more than $1000 worth, the average value being $287. Classified by occupations of operators (Table 5), the retired men and women had the highest output and business and professional men the lowest; while the output of the largest group, laborers and artisans, was a little in excess of the average for all enterprises.

TABLE 5.—AVERAGE VALUE OF AGRICULTURAL OUTPUT BY PART-TIME FARMERS, CLASSIFIED BY OCCUPATION.

Occupation	Operators		Value of output	
	Number	*Per cent*	Total	Average
Laborers and artisans	316	*60.9*	$94,670	$300
Office workers, professional and business men	138	*26.6*	32,070	232
Retired men, and women	65	*12.5*	22,385	344
Total	**519**	*100.0*	**149,125**	**287**

Land Values in Farming and Part-Time Farming

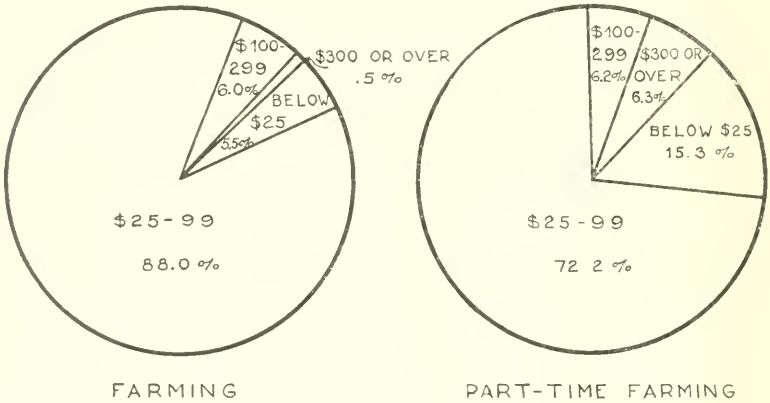
The average value of land was $98 per acre in part-time farming enterprises as compared with $52 in regular farming. (Table 6.) An analysis of the figures given in the table shows that the higher average was entirely due to a considerable percentage of the area in part-time farming which was valued at $300 and more per acre. All the land in that range of prices derived its value largely from its importance for residential purposes, and was owned by a number of part-time farmers in lots ordinarily not larger than a fraction of an acre in size. When this high-priced residential land was eliminated from the total land area, the remaining land in part-time farming proved to have a lower average value than the

TABLE 6.—DISTRIBUTION OF LAND VALUES IN FARMING AND PART-TIME FARMING.

Value per acre	FARMING				PART-TIME FARMING			
	Acres		Total value	Average price per acre	Acres		Total value	Average price per acre
	Number	*Per cent*			Number	*Per cent*		
Below $25.....	243	*5.5*	$4,400	$18	932	*15.3*	$16,350	$18
$25— 49.....	2,915	*65.4*	108,100	37	3,067	*50.2*	105,650	34
50— 74	757	*17.0*	45,500	60	1,027	*16.8*	62,500	61
75— 99.....	248	*5.6*	20,200	81	317	*5.2*	26,150	83
100— 299.....	267	*6.0*	35,900	134	382	*6.2*	66,795	175
300 or over.....	24	*.5*	16,200	675	384	*6.3*	319,825	833
Total.....	**4,454**	*100.0*	**230,300**	52	**6,109**	*100.0*	**597,270**	**98**

land in regular farming. In fact, there were found in part-time farming considerable areas of low-priced, inferior land which had been abandoned by regular agriculture. This is well demonstrated by the fact that, while only 5.5 per cent of the total area in farming was valued at less than $25 per acre, in part-time farming this low-priced land represented 15.3 per cent of the total area. (Chart 5.) As compared with regular farming, therefore, part-time farming tended to develop either on land which was important for residential purposes or on the poorer grades of agricultural land.

Chart 5. Percentage of Land of Different Values Held in Farming and Part-Time Farming in the Town of Holden.



Size of Landholdings in Part-Time Farming

The size of landholdings of part-time farmers in the town of Holden showed a wide variation, beginning with small lots not larger than a fraction of an acre, and ending with tracts of 100 acres or more. As shown in Table 7, over one-third of the total number of enterprises in Holden were less than one acre in size. Nearly another third was represented by landholdings varying in size from one to three acres. In addition to raising vegetables, the operators on some of these enterprises

TABLE 7.—PART-TIME FARMING ENTERPRISES CLASSIFIED BY SIZE OF FARM.

Size in acres	Number	*Per cent*
Below 1	180	*34.7*
1—2.9	160	*30.8*
3—9.9	61	*11.8*
10—19.9	41	*7.9*
20—29.9	21	*4.0*
30—39.9	10	*2.0*
40—49.9	7	*1.3*
50 or over	39	*7.5*
Total	**519**	*100.0*

kept large flocks of poultry, and a few of them even had a cow. Thirty-nine operators, or 7.5 per cent of the total number, had enterprises which ranged in size 50 acres and over. It must be added, however, that most of the land in these large holdings is covered by brush and woods, and is too stony or hilly to use for agricultural purposes. The possession of large areas of this submarginal land is largely responsible for the fact that part-time farmers hold a larger area of land than regular farmers.

Distribution of Live Stock in Farming and Part-Time Farming

Of the total of 604 cows reported, 444 were found in farming and 160 in part-time farming. Exactly one-half of the part-time farmers reporting cows had one cow each, 19 had two cows each, and only 4 had five or more cows each. (Table 8.)

TABLE 8.—FARMING AND PART-TIME FARMING ENTERPRISES CLASSIFIED BY NUMBER OF COWS.

Number of cows	Farmers		Part-time farmers	
	Number	*Per cent*	*Number*	*Per cent*
0	11	*16.7*	445	*85.7*
1	4	*6.0*	37	*7.1*
2	5	*7.6*	19	*3.7*
3	8	*12.1*	8	*1.5*
4	4	*6.0*	6	*1.2*
5—9	18	*27.3*	3	*.6*
10—14	6	*9.1*	0	*0.0*
15—19	5	*7.6*	1	*.2*
20 or over	5	*7.6*	0	*0.0*
Total	**66**	*100.0*	**519**	*100.0*

Farming exceeded part-time farming also in the number of horses reported, although not to the same extent as in the number of cows; but in the number of chickens reported, part-time farming exceeded farming by a considerable margin. In addition, swine, rabbits, ducks, geese, and turkeys were found in a few part-time farming enterprises.

TABLE 9.—FARMING AND PART-TIME FARMING ENTERPRISES CLASSIFIED BY NUMBER OF HORSES.

Number of horses	Farmers		Part-time farmers	
	Number	*Per cent*	*Number*	*Per cent*
0	13	*19.7*	462	*89.0*
1	22	*33.3*	43	*8.3*
2	22	*33.3*	10	*1.9*
3	8	*12.1*	3	*.6*
4 or over	1	*1.6*	1	*.2*
Total	**66**	*100.0*	**519**	*100.0*

TABLE 10.—FARMING AND PART-TIME FARMING ENTERPRISES CLASSIFIED BY NUMBER OF CHICKENS.

Number of chickens	Farmers		Part-time farmers	
	Number	*Per cent*	*Number*	*Per cent*
0	10	*15.2*	217	*41.8*
1—24	14	*21.2*	186	*35.8*
25—49	16	*24.2*	68	*13.1*
50—74	10	*15.2*	26	*5.0*
75—99	0	*0.0*	5	*1.0*
100 or over	16	*24.2*	17	*3.3*
Total	**66**	*100.0*	**519**	*100.0*

Types of Part-Time Farming

The majority of part-time farming enterprises were of a mixed nature, that is, having both crops, principally vegetables, and live stock. However, a large number of operators raised only crops, keeping no live stock. (Table 11.)

This table shows also a considerable difference in the make-up of the enterprises that had a surplus for sale, as compared with those that produced only for their own consumption. While 89.6 per cent of the first group had both crops and live stock, only 37.7 per cent of the second were of a mixed type, the rest of them specializing almost exclusively in the raising of vegetables.

TABLE 11.—TYPES OF PART-TIME FARMING ENTERPRISES.

	All enterprises		Enterprises with surplus for sale		Enterprises without surplus	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Crops only (principally vegetables)	207	*39.9*	17	*8.4*	190	*60.1*
Live stock only	11	*2.1*	4	*2.0*	7	*2.2*
Both live stock and crops	301	*58.0*	182	*89.6*	119	*37.7*
Total	**519**	*100.0*	**203**	*100.0*	**316**	*100.0*

PART-TIME FARMING IN INDUSTRIALIZED AREAS—LOWELL AND TAUNTON

The study in Lowell and Taunton areas was made in the spring and summer of 1928 and was confined to part-time farming enterprises where the heads of families were engaged as industrial laborers, artisans, farm or other manual laborers. In these areas the information from the operators was obtained on the basis of a detailed questionnaire, taking a record of the history of their occupations, date of settlement on the land, extent of farm operations, and earnings both from the farm and outside of it. Office workers and professional and business men engaged in part-time farming were not included in this part of the survey, the intention being to determine the economic and social set-up of part-time farming only for a definite group of wage earners. A further limitation on the investigation was made by including only operators who produced $100 worth or more of agricultural products during the year. A total of 115 records was taken in Lowell area and 84 in Taunton area as a sample of part-time farming enterprises with these qualifications.

Description of the Areas

Within the four towns making up the Lowell area studied, there were, in 1928, nineteen industrial plants with a total of 2,496 operatives employed.[4] The city of Lowell had at the same time 185 industrial plants with a total of about 53,000 employees.

In Taunton area there were eleven industrial plants within the towns in which the operators resided, with a total of 1,697 employees. In the city of Fall River there were 133 industrial plants with a total of 42,618 employees, and in the city of Taunton 79 industrial establishments which employed about 20,000 operatives.

In times of normal industrial activity, part-time farmers living within the investigated areas find good opportunities for employment within their districts. In the last few years, however, the conditions of employment have been rather unfavorable, due to depression in the textile industries, so that a number of operators have been employed only for a few months in the year or have worked only three or four days during the week.

Both Lowell and Taunton areas are well connected with the industrial centers around which they are situated and offer to operators fairly good facilities for communication with the place of their work. Trolley lines, trains, and busses operate in both areas, and the roads for auto traffic are in good condition. Where the farms are situated on country roads, ordinarily only short distances separate them from the main roads.

The types of soil found in these areas, as in the town of Holden, are diverse. In Taunton area there are large sections of sandy loam which, with a sufficient use of fertilizers, is well adapted to market gardening. Small areas of good valley soil are found along the Merrimac River in Lowell area and along the Taunton River in Taunton area. The average elevation of Lowell area is about 200 feet. The Taunton area is much flatter, and has an elevation of only 100 feet above sea level.

The majority of operators found their employment in the industrial centers nearest to their place of residence. The average distance to

[4] Directory of Massachusetts Manufacturers. Sampson and Murdock Co., Boston. 1928.

their places of employment was 3.8 miles in Lowell area and 5.0 miles in Taunton area. The distances traveled are shown in Chart 1 (page 109).

Table 2 (page 110) shows the methods of transportation used. The smaller percentage of operators using the automobile in Lowell area was largely due to exceptionally good electric car and bus facilities. Operators using automobiles either owned their own machines or rode in those of neighbors, sharing the expense. The most common charge for this transportation was $1.50 per week without much variation for distance traveled. Where more than one member of a family worked in about the same place, the automobile was used in preference to other available means of transportation.

Operators are classified by nationalities on the basis of the place of their birth. (Table 3, page 110). The proportion of American-born was about the same in the Lowell and Taunton areas, about one-third of all operators. The predominant foreign element in Lowell was Polish-Lithuanian; in Taunton, Portuguese.

Period of Settlement on the Present Landholdings

For the majority of operators in both areas, the first venture into part-time farming began with their settlement on the present holdings. Only 15 per cent of the operators in either area had practiced part-time farming on holdings other than those they occupied at the time of the investigation.

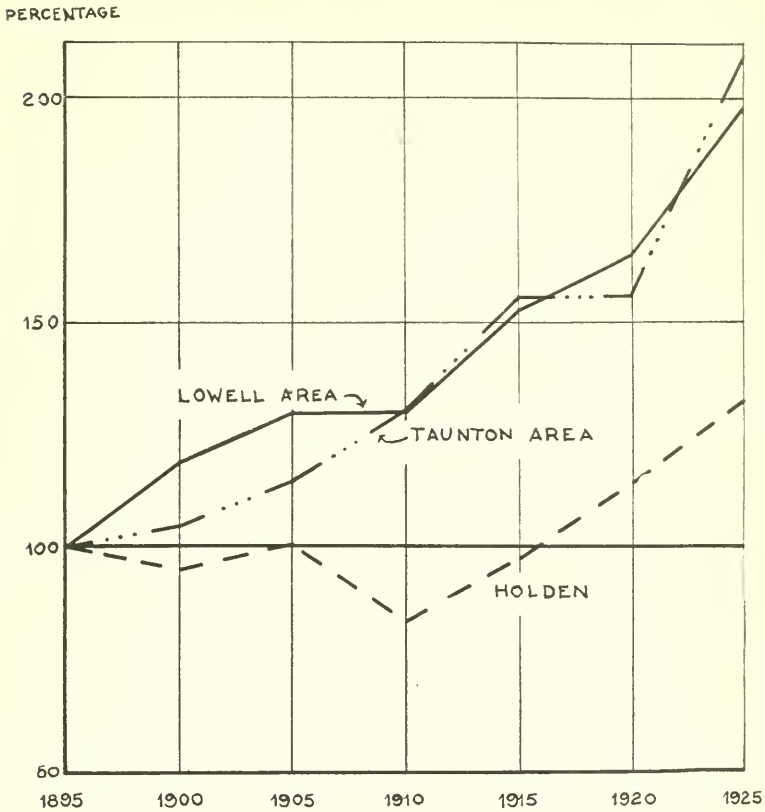
TABLE 12.—PERIOD OF SETTLEMENT OF PART-TIME FARMERS ON THEIR PRESENT LANDHOLDINGS.

Year	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Up to 1910.....	6	*5.2*	8	*9.5*
1910—1914.....	16	*13.9*	9	*10.7*
1915—1919.....	22	*19.1*	17	*20.3*
1920—1924.....	48	*41.8*	30	*35.7*
1925—1927.....	23	*20.0*	20	*23.8*
Total.....	**115**	*100.0*	**84**	*100.0*

Table 12 shows that only 5.2 per cent of the operators in Lowell area and 9.5 per cent in Taunton area had settled on the present holdings prior to 1910. On the other hand, 61.8 per cent in the first, and 59.5 per cent in the second area began to operate their present enterprises after 1920, or in the eight-year period prior to the present investigation. When due allowance is made for the ages of operators, and the fact that some of the earlier settlers died or moved out, these figures are still large enough to warrant the conclusion that there has been an increase in the rate of settlement within the last decade or so. This is also substantiated by the fact that 32.2 per cent of the operators in Lowell area and 23.8 per cent in Taunton area, almost all of whom settled within recent years, acquired merely land on which they erected buildings and developed new enterprises.

The rate of growth of population within the last thirty years in small towns and semi-rural districts of the State also indicates that there has been an exceptionally large influx of people into the country, beginning

Chart 6. Changes in Population in Investigated Areas, 1895-1925. 1895=100.

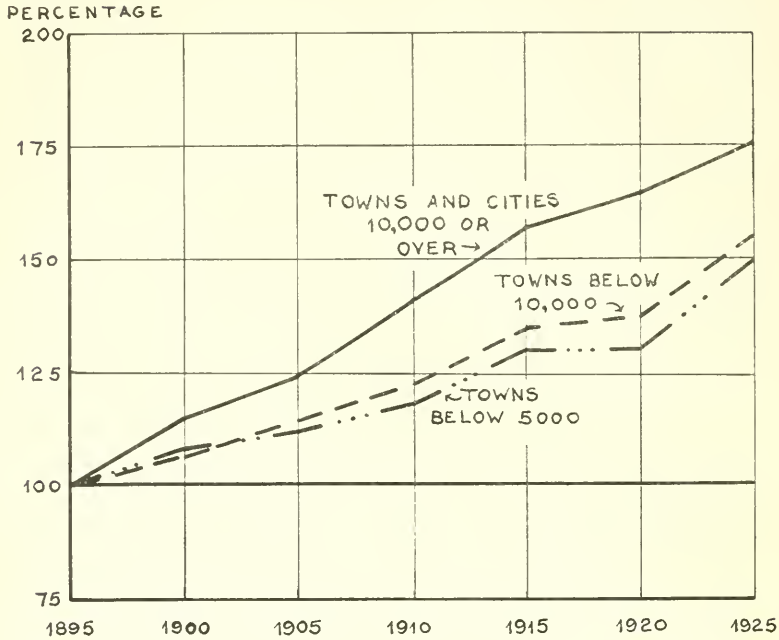


with 1920. Charts 6 and 7 show that, both in the areas investigated and in the total of towns of less than 5,000 and less than 10,000, the highest increases in population came in the five-year period from 1920 to 1925. On the other hand, all the cities and towns with population of over 10,000 showed a more or less uniform growth through the entire period under observation, the greatest increase occurring in the five-year period from 1910 to 1915.

Age of Operators

The average age of operators was found to be about the same in both areas, 45.7 years in Lowell area and 45.2 in Taunton area. The distribution of ages, however, does not show the same similarity. (Table 13.) While 15.5 per cent of the operators in Taunton area were below the age of 35, in Lowell area this group included only 8.7 per cent. Taunton area exceeded Lowell area also in the percentage of operators over 45 years old, but the latter showed a greater percentage in the age group between 35 and 45 years. The part-time farmers in Lowell area, therefore, were represented to a greater extent by the middle age group, while in Taunton area there was a predominance of younger and older men.

Chart 7. Changes in Population in Massachusetts Towns and Cities by Size Groups, 1895-1925. 1895=100.



In the latter area, many sons of Portuguese fathers, even those born in this country, instead of moving into the city, established themselves on the land and engaged in farming on a full- or part-time basis. This became more easily possible because the Portuguese parents gave liberal financial assistance to their sons for acquisition of small farming enterprises. Nevertheless, the presence in Taunton area of a comparatively large number of young operators with insufficient savings resulted in a higher percentage of tenancy as compared with Lowell area.

Table 13.—Distribution of ages of operators.

Age of operator	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Under 30.....	0	*0.0*	6	*7.2*
30—34.9.....	10	*8.7*	7	*8.3*
35—39.9.....	23	*20.0*	11	*13.1*
40—44.9.....	22	*19.1*	12	*14.3*
45—49.9.....	21	*18.3*	22	*26.2*
50—59.9.....	30	*26.1*	18	*21.4*
60 or over.....	9	*7.8*	8	*9.5*
Total.....	**115**	*100.0*	**84**	*100.0*

Record of Families

Table 14 shows both the actual number of persons in the families investigated, and the number expressed as adult equivalent units.[5] Both in the average number of children at home and the number of children dependent on the head, Lowell shows a higher figure. This is due partly to the differences in the distribution of ages of operators and their children, and partly to the fact that in Taunton area the children of Portuguese operators were found at work at an earlier age than those of other operators.

TABLE 14.—RECORD OF FAMILIES.

	Number of families	Number of persons		Adult equivalent	
		Total	Average	Total	Average
Lowell Area					
Total number living in house	115	688	6.0	561	4.9
Number dependent on head	115	631	5.5	504	4.4
Children at home	105	440	4.2	...	...
Children dependent on head	104	396	3.8	...	...
Dependents outside immediate family	9	12	1.3	...	...
Children working outside and other independents	37	57	1.5	...	...
Taunton Area					
Total number living in house	84	465	5.5	404	4.8
Number dependent on head	84	385	4.6	324	3.9
Children at home	75	274	3.7	...	...
Children dependent on head	68	209	3.1	...	...
Dependents outside immediate family	6	8	1.3	...	...
Children working outside and other independents	41	80	2.0	...	...

Present Occupation of Operators

The majority of operators in both Lowell and Taunton areas, as shown in Table 15, were engaged as skilled and unskilled industrial laborers. Of the other types of laborers, Lowell area had a higher percentage of general laborers, and Taunton area led in the number of farm laborers and artisans.

Occupation of Operators Prior to Entering Part-Time Farming

Only two operators in Lowell area and five in Taunton area were

[5] There are several systems of estimating adult equivalent units. Most of them, however, are built on the basis of food consumption requirements of children of different ages. For the purposes of general discussion in this study, all the children under 12 were assigned the weight of one-half of a unit; all other persons were giveu the weight of a full unit.

TABLE 15.—OCCUPATION OF PART-TIME FARMERS.

Occupation	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Farm laborers.....	1	*.9*	8	*9.5*
Industrial laborers	89	*77.4*	62	*73.8*
General laborers..	19	*16.5*	5	*6.0*
Artisans.....	6	*5.2*	9	*10.7*
Total.....	**115**	*100.0*	84	*100.0*

regular farmers before they became part-time farmers.[6] The rest were engaged in one or more of the following types of labor: Industrial labor, general labor, farm labor, and artisan trades.

Table 16 shows the number of operators engaged in each type of labor mentioned, and the average number of years spent by them in that employment. The figures indicate that industrial employment had been the most important type of occupational experience for the operators prior to their entering part-time farming. Outside of independent farming, artisan trades in Lowell area and general labor in Taunton area had given employment to the smallest number of operators in the same period of time.

TABLE 16.—LENGTH OF TIME SPENT BY OPERATORS IN DIFFERENT OCCUPATIONS BEFORE BECOMING PART-TIME FARMERS.

Occupation	Lowell area			Taunton area		
	Operators*		Average number of years	Operators*		Average number of years
	Number	*Per cent*		Number	*Per cent*	
Farm labor.....	73	*63.5*	8.1	43	*51.2*	10.6
Industrial labor.....	92	*80.0*	16.3	68	*80.9*	14.3
General labor.....	15	*13.0*	15.5	5	*5.9*	9.8
Artisan.....	8	*6.9*	13.6	10	*11.9*	9.4
Independent farming....	2	*1.7*	9.5	5	*5.9*	11.3

*Many operators had previous experience in two or more occupations.

Early Training of Operators and Their Wives

Although most of the operators entered part-time farming from various industrial occupations, the majority of them were brought up and received their early training on farms. Especially is this true with respect to foreign-born operators. (Table 17.) In Lowell area 78.3 per cent of the operators, and in Taunton area 76.2 per cent, came originally from farms. If only American-born operators are considered, the figures for those reared on farms are 53.7 per cent in Lowell area and 66.7 per cent in Taunton area. The data with regard to the early environment of wives show, with some slight variations, similar relations.

[6] This refers only to experience in independent farming in this country. Foreign-born operators, with a few exceptions, were engaged as farm laborers or dependent tenants before coming to this country. The latter group, from the American standpoint, may well be designated as a class of farm laborers.

TABLE 17.—NUMBER OF FARM AND CITY-BRED OPERATORS AND WIVES.

	Lowell area		Taunton area	
	Farm-bred	City-bred	Farm-bred	City-bred
Operators:				
American-born	22	19	18	9
Foreign-born	68	6	46	11
Total	**90**	**25**	**64**	**20**
Wives:				
American-born	25	20	19	10
Foreign-born	59	4	48	5
Total	**84**	**24**	**67**	**15**

For the families where either husband or wife had an agricultural background, the starting of farming operations naturally presented no such difficulties as were found by the families in which neither had ever lived on a farm. In the latter case, the operators had to rely largely on the assistance of their neighbors and use the method of trial and error until they mastered the rudiments of agriculture. But once city-bred operators learned enough about agriculture to carry on the necessary operations, they displayed, as a general rule, a great interest in their farming activities, often greater than the operators who originally came from a rural environment.

Reasons for Entering Part-Time Farming

As already stated, the majority of operators prior to becoming part-time farmers lived in the cities. In order to determine the main factors responsible for their entering part-time farming, the operators were asked to tell what induced them to change their former mode of living and settle on the land. Inasmuch as many operators mentioned several reasons for this change, it has been difficult in some cases to determine the most important factor. Nevertheless an attempt has been made to single out in each case the outstanding factor in the decision to settle on the land.

As shown in Table 18, 45 per cent of the operators in Lowell area and 54 per cent in Taunton area became part-time farmers in order to increase

TABLE 18.—OPERATORS CLASSIFIED BY THE REASON FOR ENTERING PART-TIME FARMING.

Reason for part-time farming	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Increased earning and cheaper living	52	*45.3*	46	*54.7*
Improved health and better housing	54	*47.0*	14	*16.7*
Unemployment	2	*1.7*	3	*3.6*
Independence in old age	2	*1.7*	9	*10.7*
Love of country life	3	*2.6*	11	*13.1*
Inheritance or gift	2	*1.7*	1	*1.2*
Total	**115**	*100.0*	**84**	*100.0*

their earnings or cut down living expenses. In their association with part-time farming these factors often cannot be separated one from the other.

The consideration of improving health and housing conditions came next in importance, particularly to the operators with large families. Although the cost of housing in part-time farming was not always lower, they found in the country more room space, fresh air, more light, and better playgrounds for the children, who were freed from the dangers of congested city traffic. Operators who settled on the land in order to improve their own health or that of some member of the family, as a rule became accustomed and attached to country life and work so that they remained in part-time farming after the immediate cause of the change of residence was removed.

Unemployment was an immediate cause of entering part-time farming for a few operators in both areas. The use of part-time farming in times of unemployment is, however, of some significance to all engaged in it, and many operators with large families would have found themselves helpless without this additional income.

Some became part-time farmers in order to develop a small enterprise which would supply at least a part of their living when they could no longer find employment on account of old age. Although only a few in each area mentioned this reason as responsible for their decision to settle on the land, its significance, like that of the unemployment factor, seemed to be felt by a good many part-time farmers.

In some cases the operators could not assign a definite reason for moving into the country and settling on the land, except for the general statement that they preferred country to city life.

Size of Landholdings

The average size of landholdings for all part-time farming enterprises is shown in Table 19. As compared with rented enterprises, the average size of owned enterprises was slightly larger in the Taunton area, and smaller in the Lowell area.

TABLE 19.—SIZE OF OWNED AND RENTED LANDHOLDINGS IN PART-TIME FARMING ENTERPRISES.

Landholdings	Lowell area			Taunton area		
	Number	Per cent	Average size	Number	Per cent	Average size
			Acres			*Acres*
Owned	110	*95.7*	6.7	70	*83.3*	9.1
Rented	5	*4.3*	9.5	14	*16.7*	7.1
Total	**115**	*100.0*	**7.0**	**84**	*100.0*	**9.0**

The distribution of sizes of all enterprises, as shown in Table 20, indicates that almost one-half of the holdings in both areas were less than three acres in size. The higher percentage of large landholdings (10 acres or over) in Taunton area was primarily due to the comparative prevalence of seasonal part-time farming.

TABLE 20.—DISTRIBUTION OF SIZES OF LANDHOLDINGS.

Acres	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Under 1	27	*23.5*	19	*22.6*
1— 1.9	12	*10.4*	12	*14.3*
2— 2.9	18	*15.7*	8	*9.5*
3— 3.9	6	*5.2*	5	*5.9*
4— 4.9	10	*8.7*	1	*1.2*
5— 5.9	5	*4.3*	3	*3.6*
6— 9.9	9	*7.8*	9	*10.7*
10—14.9	14	*12.2*	3	*3.6*
15 or over	14	*12.2*	24	*28.6*
Total	**115**	*100.0*	**84**	*100.0*

Sources of Land Supply for Part-Time Farmers

In order to obtain small landholdings of the size needed for their purpose, the operators drew upon several different sources of land supply. Some of them purchased their landholdings from part-time farmers who had already established themselves in the community, while others bought their land from regular farmers. Apparently, however, these sources were insufficient to satisfy the demand for small landholdings in the investigated areas, for several real estate dealers and subdivision companies bought large tracts of land which they subdivided into lots of different sizes and offered for sale. A few of these agencies put up inexpensive buildings and offered them for sale together with the land. By enabling the operators to purchase small holdings in the sizes which fitted their needs, and often by extending to them a liberal long-term credit, these agencies proved to be a real factor in fostering the development of part-time farming. Those who purchased their land from real estate agencies, however, ordinarily paid prices considerably higher than did the operators who purchased equally good land from private owners.

Value of Purchased Property and Terms of Acquisition

Almost all operators, as shown in Table 19, were owners of their landholdings. In fact, the condition of ownership was found to be a fundamental feature of part-time farming, and most of the operators would neither care nor be able to settle on small landholdings if they could not become owners of their enterprises.

A number of operators who could not afford to purchase small holdings equipped with buildings suited to their needs, or who could not find them, purchased land and erected the buildings afterward. (Table 21.)

As shown in Table 22 practically all operators in both areas carried one or more mortgages on their property. The mortgage indebtedness of those who placed only one mortgage on their property was slightly more than half the purchase price in both areas. Where more than one mortgage was assumed, the property was mortgaged to the extent of three-fourths of its purchase price.

TABLE 21.—AVERAGE PRICE PAID FOR PROPERTY BY OPERATOR OWNERS.

Property purchased	Lowell area			Taunton area		
	Number	Per cent	Average price	Number	Per cent	Average price
Land with buildings.....	69	*65.1*	$2,546	47	*70.1*	$3,140
Land only.....	37	*34.9*	529	20	*29.9*	518
Total.....	**106***	*100.0*	**1,842**	**67***	*100.0*	**2,357**

*Does not include those who were previously engaged in regular farming on the same holdings.

TABLE 22.—TERMS OF ACQUISITION OF PROPERTY EQUIPPED WITH BUILDINGS.

Terms of purchase	Lowell Area				Taunton Area			
	Number	Average price	Mort'ge debt	Per cent of price	Number	Average price	Mort'ge debt	Per cent of price
Cash.....	4	$1,050	....	....	7	$1,700	....	....
One mortgage.....	55	2,654	$1,434	*54.0*	28	3,107	$1,646	*53.0*
Two or more mortgages.....	10	3,380	2,590	*76.6*	12	4,058	2,983	*73.5*

Crop Acreage

As shown in Table 23 about one-fifth of the total acreage was in crops, exclusive of hay. This was about one half of the total improved acreage in part-time farming, the other half being in hay and pasture. The crops grown were almost exclusively vegetables and small fruits. There were a few part-time farming enterprises which specialized in the cultivation of fruit trees. The average number of acres in crops was 1.3 in Lowell area and 1.8 in Taunton, but more than half of the enterprises had less than one acre each. (Table 24.) Only two of the operators in Lowell area had more than 5 acres in crops; but in Taunton area, where a number of operators raised vegetables on a commercial basis, ten of the enterprises had more than 5 acres in crops.

TABLE 23.—LAND UTILIZATION IN PART-TIME FARMING ENTERPRISES.

	Lowell area			Taunton area		
	Acres	Per cent of total area	Average per enterprise	Acres	Per cent of total area	Average per enterprise
Improved land.....	274	*33.9*	2.4	308	*40.6*	3.7
Crop land exclusive of hay	147	*18.2*	1.3	149	*19.7*	1.8
Unimproved land.....	534	*66.1*	4.6	450	*59.4*	5.3

Chart 8. Distribution of Values of Owned Part-Time Farming Enterprises in Lowell and Taunton Areas.

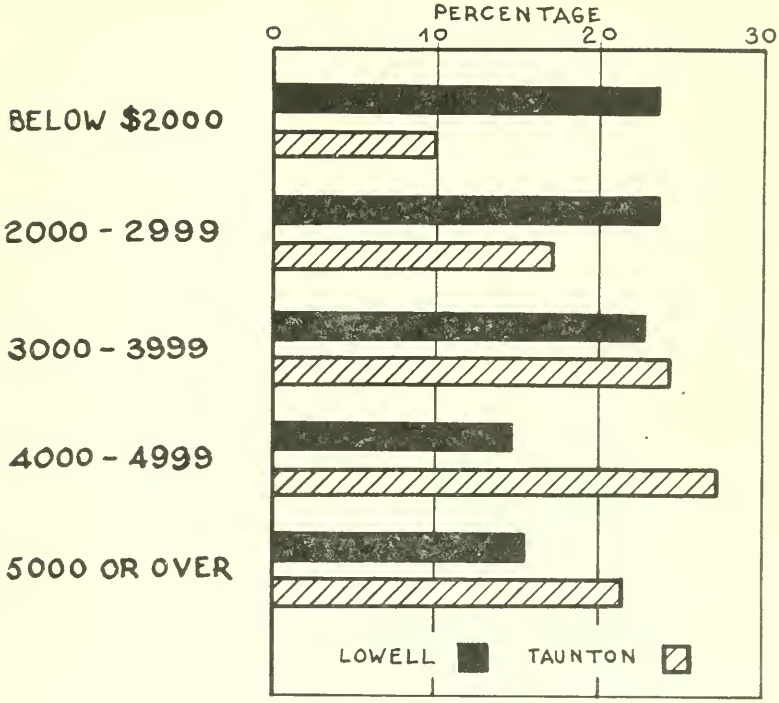


TABLE 24.—DISTRIBUTION OF CROP LAND IN PART-TIME FARMING ENTERPRISES.
(Exclusive of Hay)

Acres	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Below 0.5.....	20	*17.4*	17	*20.2*
0.5— .9.....	44	*38.2*	32	*38.1*
1.0— 2.9.....	45	*39.1*	18	*21.4*
3.0— 4.9.....	4	*3.5*	7	*8.4*
5.0— 9.9.....	1	*.9*	8	*9.5*
10.0—14.9.....	0	*0.0*	2	*2.4*
15 or over.....	1	*.9*	0	*0.0*
Total.....	115	*100.0*	84	*100.0*

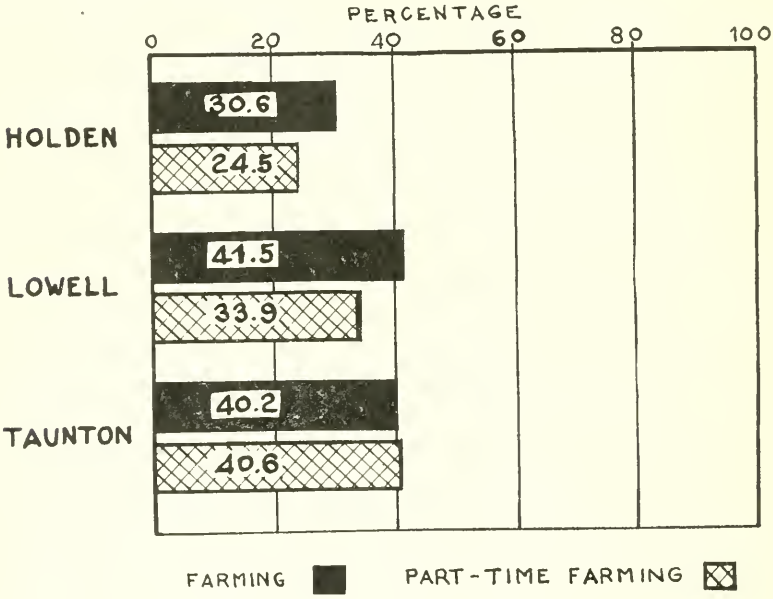
Improved Acreage in Part-Time Farming

It has been the practice of a good many part-time farmers to settle on unimproved land covered by brush and stones, and then by clearing it in their spare time, to bring the land into productive use. By following this practice the operators have been able to acquire their land at a low

price and obtain the benefit of the enhanced value of their holdings resulting from the improvements. Because of this tendency, however, the percentage of improved land in part-time farming proved to be lower than in regular farming.

From Chart 9, where the proportion of improved land in farming as given by the United States Census is compared with that in part-time farming, it will be seen that the latter had a smaller percentage of improved acreage both in the town of Holden and in Lowell area. Only in Taunton area did it even slightly exceed the percentage of improved land in regular farming. This was largely due to the presence in that area of Portuguese operators, who were found to be the most active in improving their land.

Chart 9. Percentage of Improved Land in Farming as Given by the United States Census, compared with the Percentage in Part-Time Farming in Lowell and Taunton Areas and the Town of Holden.



Types of Part-Time Farming

Although most of the part-time farmers raised vegetables and kept some live stock to satisfy the immediate needs of their families for agricultural products, when it came to producing a surplus for sale they specialized in the type of farming best adapted to the local physical and marketng conditions as regular farmers ordinarily do. From Table 25 it will be seen that during the year under consideration the value of output in live stock and live-stock products in Lowell area was two-thirds of the value of total output, while in Taunton area the return from the same source was only half the value of the total output.

The condition of soil and general character of farming in Taunton area

led to specialization by part-time farmers in the raising of vegetables and strawberries. As these enterprises are based on seasonal labor, there was a larger number of seasonal part-time farmers in Taunton area than in Lowell area.

TABLE 25.—VALUE OF AGRICULTURAL OUTPUT OF PART-TIME FARMERS.

	Value of output	Per cent of total value	Number of operators reporting	Average per operator
Lowell Area				
Live-stock products	$36,235	*67.8*	110	$329
Crops	17,180	*32.2*	115	149
Total	**53,415**	*100.0*	**115**	**464**
Taunton Area				
Live-stock products	$27,644	*49.5*	76	$364
Crops	28,165	*50.5*	84	335
Total	**55,809**	*100.0*	**84**	**664**

Live Stock in Part-Time Farming

With very few exceptions, part-time farmers in Lowell and Taunton areas, in addition to raising vegetables or other crops, kept some live stock or poultry. As shown in Table 26, about one-third of all enterprises had cows, but most of them had only one cow. By having one cow, the operators with large families obtained enough milk for their own needs. The keeping of two cows, or even one cow for a small family, ordinarily involved the sale of surplus milk. Since a small surplus of milk had to be disposed of largely to the neighbors, the operators in well-supplied neighborhoods often found it more profitable to buy milk than to keep a cow; but those who kept three or more cows found good facilities for disposing of their surplus milk by selling it to different marketing agencies.

The keeping of poultry was found to be the favorite and most convenient form of part-time farming. The majority, however, had less than 25 birds each.

Swine were largely kept by operators who had some waste products on their farms or who had easy access to garbage sources in the city. Feeding swine with purchased feed was found to be generally unprofitable. Table 26 shows that fewer operators kept swine than kept cows. The average number of swine per enterprise was 2.5 in Lowell area and 2.2 in Taunton area.

Horses were kept only in the larger part-time farming enterprises. About one-fifth of the enterprises had horses, but there was none with more than one horse. Operators who kept no horses ordinarily hired them from their neighbors for plowing or other work where a horse was needed.

In addition, several operators kept rabbits, goats, and different kinds of poultry.

TABLE 26.—LIVE STOCK IN PART-TIME FARMING ENTERPRISES.

	LOWELL AREA				TAUNTON AREA			
	Operators reporting		Number of animals		Operators reporting		Number of animals	
	Number	Per cent	Total	Average	Number	Per cent	Total	Average
Cows.....	40	*34.8*	58	1.4	29	*34.5*	47	1.6
Horses.....	23	*20.0*	23	1.0	19	*22.6*	19	1.0
Chickens....	107	*93.0*	3,149	29.4	69	*82.1*	1,891	27.4
Swine.....	27	*23.5*	67	2.5	24	*28.6*	52	2.2

Live Stock Owned by Operators of Various Nationalities

The distribution of live stock among operators of different nationalities led to the conclusion that in general American-born operators engaged to a lesser extent in the keeping of live stock. Although the percentage of American-born operators who kept poultry (Table 27) was almost as large as that of foreign-born, a smaller proportion of them kept cows and swine. The largest proportion of cows and swine belonged to Polish-Lithuanian operators in Lowell area and Portuguese in Taunton area, while French Canadian operators occupied an intermediate position between these foreign groups and American-born operators.

This condition was apparently due both to the willingness of foreign-born operators to spend more time in attending to live stock at all times of the year, and to a greater degree of participation of their wives and children in farming operations. However, in the matter of raising crops, where the labor involved is of a more seasonal nature, the American-born operators were more willing to extend their farm operations. From

TABLE 27.—LIVE STOCK OWNED BY OPERATORS OF VARIOUS NATIONALITIES.

Lowell Area

Nationality	COWS		CHICKENS		SWINE	
	Operators reporting	Average per enterprise	Operators reporting	Average per enterprise	Operators reporting	Average per enterprise
	Per cent	*Number*	*Per cent*	*Number*	*Per cent*	*Number*
American.....	*17.1*	2.4	*95.1*	30.7	*7.3*	1.7
Polish and Lithuanian...	*63.9*	1.1	*97.2*	22.3	*87.2*	2.5
French Canadian.....	*40.0*	1.3	*100.0*	42.1	*10.0*	3.0

Taunton Area

American.....	*22.2*	1.3	*77.8*	34.4	*14.8*	1.8
French Canadian.....	*58.5*	2.6	*92.3*	32.0	*7.7*	2.0
Portuguese.....	*47.4*	1.3	*80.6*	19.1	*47.2*	2.4

Table 28 it will be seen that, although the average value of crops produced in Lowell area by American-born was below that for other operators, in Taunton area it occupied first place.

TABLE 28.—AVERAGE VALUE OF CROPS BY NATIONALITY OF OPERATORS.

Nationality	Lowell area	Taunton area
American	$135	$385
Polish and Lithuanian	148	....
French Canadian	280	207
Portuguese	....	366

Value of Agricultural Output

The total value of agricultural output of part-time farming enterprises is shown in Table 25, while Table 29 classifies these enterprises by value of output. It was found that the average production per operator was much larger in the Taunton area, and the number of large producers formed a larger percentage of the total.

TABLE 29.—DISTRIBUTION OF VALUES OF AGRICULTURAL OUTPUT.

Value of output	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
$100—$199	22	*19.1*	14	*16.7*
200— 299	33	*28.7*	14	*16.7*
300— 399	10	*8.7*	10	*11.9*
400— 499	11	*9.6*	6	*7.1*
500— 749	22	*19.1*	16	*19.0*
750— 999	9	*7.8*	11	*13.1*
1000 or over	8	*7.0*	13	*15.5*
Total	**115**	*100.0*	**84**	*100.0*

Proportion of Agricultural Output Sold and Consumed

In planning their production the majority of operators were guided largely by the consumption needs of their families, and those who did not produce any surplus for sale ordinarily raised enough vegetables and live-stock products to fill this need. Hence, in spite of considerable difference in the average size of agricultural output between the two areas, the average value of products consumed showed only a slight difference. (Table 30.)

While the families in Lowell area consumed 63.8 per cent of the total value of their production, in Taunton area the proportion consumed was only 45.2 per cent of the total. This difference appears to be still more significant when the figures on proportions consumed are taken separately for crops and live-stock products. The proportion of live-stock products taken for consumption bore about the same relation to the total in both areas, but the share of total crop production consumed in Lowell area was more than twice as large as in Taunton area. Hence, the operators in

TABLE 30.—VALUE OF HOME-GROWN PRODUCTS CONSUMED.

	Lowell Area			Taunton Area		
	Value consumed	Per cent of value produced	Average for all families	Value consumed	Per cent of value produced	Average for all families
Live-stock products	$20,068	*55.4*	$174	$14,300	*51.7*	$170
Crops	14,000	*81.5*	122	10,910	*38.7*	130
Total	**34,068**	*63.8*	**296**	**25,210**	*45.2*	**300**

TABLE 31.—DISTRIBUTION OF PART-TIME FARMING ENTERPRISES BY VALUE OF PRODUCTS CONSUMED.

Value of products consumed	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Under $100	1	*0.9*	2	*2.4*
$100— 199	41	*35.7*	24	*28.6*
200— 299	32	*27.8*	28	*33.3*
300— 399	9	*7.8*	13	*15.5*
400 or over	32	*27.8*	17	*20.2*
Total	**115**	*100.0*	**84**	*100.0*

TABLE 32.—VALUE OF PRODUCTS SOLD FROM PART-TIME FARMING ENTERPRISES.

Lowell Area

	Value sold	Per cent of value produced	Per cent of operators reporting	Average per operator
Live-stock products	$16,167	*44.6*	53.0	$265
Crops	3,180	*18.5*	35.7	78
Total	**19,347**	*36.2*		**251**

Taunton Area

Live-stock products	$13,344	*48.3*	56.0	$171
Crops	17,255	*61.3*	48.8	421
Total	**30,599**	*54.8*		**471**

Lowell area had very few vegetables and other crops for sale, but sold largely live-stock products. The Taunton figures, as shown in Table 32, were greater both in the percentage of operators having a surplus for sale, and in the average amount sold per operator.

TABLE 33.—DISTRIBUTION OF PART-TIME FARMING ENTERPRISES BY VALUE OF PRODUCTS SOLD.

Value of products sold	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Under $50.....	12	*15.6*	4	*6.2*
$50— 74.....	11	*14.0*	8	*12.3*
75— 99.....	6	*7.8*	6	*9.2*
100— 199.....	16	*20.7*	10	*15.4*
200— 299.....	10	*13.0*	7	*10.8*
300— 499.....	14	*18.2*	9	*13.8*
500 or over.....	8	*10.4*	21	*32.3*
Total.....	**77**	*100.0*	**65**	*100.0*

Family Farm Income

The net farm income from part-time farming enterprises was arrived at by subtracting all farm expenses, including tax on land, from the value of total agricultural output. As a result it was found (Table 34) that the average net farm income for all part-time farming enterprises was $313 in Lowell area and $454 in Taunton area. As compared with this, the average farm income for seasonal part-time farming was much higher in both areas.

The distribution of farm incomes for all operators is shown in Table 35. In Taunton area, with its large number of seasonal part-time farmers, almost one-third of all operators had a farm income of more than $500 each, while in Lowell area the proportion was only one-tenth.

TABLE 34.—FAMILY FARM INCOME IN PART-TIME FARMING.

	Lowell Area			Taunton Area		
	All operators	Regular part-time farmers	Seasonal part-time farmers	All operators	Regular part-time farmers	Seasonal part-time farmers
Value of output:*						
Total.....	$55,938	$49,170	$6,768	$57,435	$25,418	$32,017
Average per family....	486	451	1,128	684	424	1,334
Farm expenses:						
Total.....	19,928	17,342	2,586	19,285	8,563	10,722
Average per family....	173	159	431	230	143	447
Farm income:						
Total.....	36,010	31,828	4,182	38,150	16,855	21,295
Average per family....	313	292	697	454	281	887

*In addition to the value of farm products, this includes other income accruing to the farm.

Time Devoted to Part-Time Farming by Operators and Their Families

As a general rule, the agricultural work in part-time farming enterprises has been carried on by operators with considerable help from their families. In fact, some types of agricultural activities, like keeping poultry and live stock, would have been almost impossible if there had not

TABLE 35.—DISTRIBUTION OF PART-TIME FARMING ENTERPRISES BY FARM INCOME.

Farm income	Lowell Area		Taunton Area	
	Number	*Per cent*	*Number*	*Per cent*
Under $100.....	5	*4.3*	4	*4.7*
$100— 199.....	43	*37.4*	23	*27.4*
200— 299.....	23	*20.0*	10	*11.9*
300— 399.....	22	*19.1*	13	*15.5*
400— 499.....	11	*9.6*	8	*9.5*
500 or over....	11	*9.6*	26	*31.0*
Total.....	**115**	*100.0*	**84**	*100.0*

been somebody at home to take care of them in the absence of the head of the family.

On the basis of information obtained in the investigation, an estimate was made of the total time spent in farming operations, and the proportion contributed by each member of the family.[7] (Table 36.) The contribution of working time by children was less in Lowell area than in Taunton area, due partly to the fact that in seasonal part-time farming enterprises, which were more prevalent in the latter area, the work of school children could be utilized more fully in the summer time. In Lowell area, with the enterprises specialized in keeping poultry and live stock, and demanding a more or less uniform amount of working time throughout the year, the wives contributed a larger percentage of the total labor. Barring a few exceptional cases, the work in part-time farming enterprises was not burdensome to the wives and children, and was generally performed by them with considerable interest and willingness.

TABLE 36.—NUMBER OF HOURS DEVOTED TO PART-TIME FARMING BY MEMBERS OF THE FAMILY—AVERAGE PER ENTERPRISE.

	Lowell area		Taunton area	
	Hours spent*	*Per cent of total*	Hours spent*	*Per cent of total*
Operators.....	641	*47.8*	779	*48.5*
Wives.....	400	*29.9*	328	*20.5*
Children 16 years old and over.	140	*10.4*	236	*14.7*
Children under 16.....	124	*9.3*	173	*10.8*
Others.....	35	*2.6*	89	*5.5*
Total.....	**1340**	*100.0*	**1605**	*100.0*

*Expressed in adult equivalent units.

Average Return per Hour of Labor

As shown in Table 37, the average return per hour of labor for all part-time farming enterprises was higher in Taunton area than in Lowell area, due partly to the difference in the types of farming. The operators in Taunton area specialized in the growing of vegetables and straw-

[7] The work of women and children was expressed in adult male equivalent units on the basis of a table published by L. F. Garby in the University of Minnesota Farm Management Manual, 1925.

TABLE 37.—AVERAGE INCOME AND RETURN PER HOUR OF LABOR SPENT IN PART-TIME FARMING.

	Lowell area	Taunton area
Average farm income.....	$309	$454
Average number of hours spent	1,340	1,605
Return per hour.....	$0.23	$0.28

berries, which under favorable weather and marketing conditions brought good returns. There were indications, however, that increased competition from other areas was bringing down prices on special types of vegetables, and many operators were inclined to curtail their vegetable production. By marketing their products in larger quantities the seasonal part-time farmers were able to send them to central markets and obtain higher prices. The average return per hour of labor in Taunton area was 31 cents for seasonal part-time farming as compared with 26 cents for regular part-time farming enterprises. (Table 38.)

TABLE 38.—COMPARISON OF REGULAR AND SEASONAL PART-TIME FARMING ENTERPRISES IN TAUNTON AREA.

	Regular	Seasonal
Number of enterprises.....	60	24
Size of landholdings..... *acres*	5.03	18.99
Crop land, exclusive of hay...*acres*	.82	4.15
Improved land.....*acres*	1.82	8.22
Agricultural output:		
Crops.....	$158	$778
Live-stock products.....	$201	$495
Total farm output.....	$424	$1,334
Total farm expenses.....	$143	$447
Farm income.....	$281	$887
Hours of labor.....	1,102	2,862
Return per hour.....	$0.26	$0.31
Operator's non-farm labor income	$1,206	$765
Income from other sources.....	$279	$334
Value of land and buildings.....	$3,348	$4,250
Value of house.....	$2,464	$2,560
Housing costs.....	$329	$319

Most operators were inclined to put a certain premium on the work performed in their own enterprises, and when the remuneration in outside employment was not much in excess of what they could earn by working on the land, they preferred to do the latter. They claimed that by working at home they enjoyed a certain independence in planning their own work and freedom from outside compulsion and supervision. This is one of the reasons why the return from agricultural activities of part-time farmers will probably always be somewhat lower than wages paid

by industry. In addition, the work in part-time farming enterprises brings a return for the time spent by women and children, who ordinarily are not engaged in any other remunerative employment.

Length of Time Employed and Wages of Operators

Due to the general depression in the textile industries, the condition of employment in the areas covered by this investigation was not very satisfactory, and affected especially the operators in Lowell area. There were some operators who, while working throughout the year, were occupied only three or four days a week. Of those who were employed on a full-time basis, the majority worked five and one-half days a week. The average number of working days per week for all operators is shown in Table 39.

TABLE 39.—LENGTH OF TIME EMPLOYED AND WAGES OF OPERATORS.

	Lowell area	Taunton area
Average hours per day	8.3	9.8
Average hours per week	44.8	51.9
Average days per week	5.4	5.3
Average weeks employed	42.8	40.9
Average wages per week	$28	$27
Average wages per year	$1,216	$1,080

Owing to the presence in Taunton area of a considerable number of seasonal part-time farmers, the average number of weeks of employment during the year was slightly lower than in Lowell area. On the whole, however, the condition of employment was better in Taunton area; and when only regular operators are taken into consideration, the average number of working weeks was higher than in Lowell area.

TABLE 40.—DISTRIBUTION OF WEEKLY AND YEARLY WAGES.

Wages	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Per Week				
Under $20	10	*8.7*	5	*6.0*
$20— 29	62	*53.9*	62	*73.8*
30— 39	31	*26.9*	9	*10.7*
40— 49	5	*4.4*	5	*6.0*
50 or over	7	*6.1*	3	*3.5*
Total	**115**	*100.0*	**84**	*100.0*
Per Year				
Under $500	1	*0.9*	6	*7.1*
$500— 749	13	*11.3*	14	*16.7*
750— 999	20	*17.4*	9	*10.7*
1000—1249	30	*26.1*	26	*31.0*
1250—1499	20	*17.4*	19	*22.6*
1500—1749	20	*17.4*	5	*6.0*
1750—1999	5	*4.3*	4	*4.7*
2000 or over	6	*5.2*	1	*1.2*
Total	**115**	*100.0*	**84**	*100.0*

Since the seasonal part-time farmers did not have to depend so much upon their outside employment, and were employed largely during the winter months when their farming operations were completed, they were willing and often had to accept lower wages and work longer hours. Mainly for this reason, the weekly wages of operators in Taunton area were slightly lower than in Lowell area, in spite of the fact that the average number of working hours per week was higher.

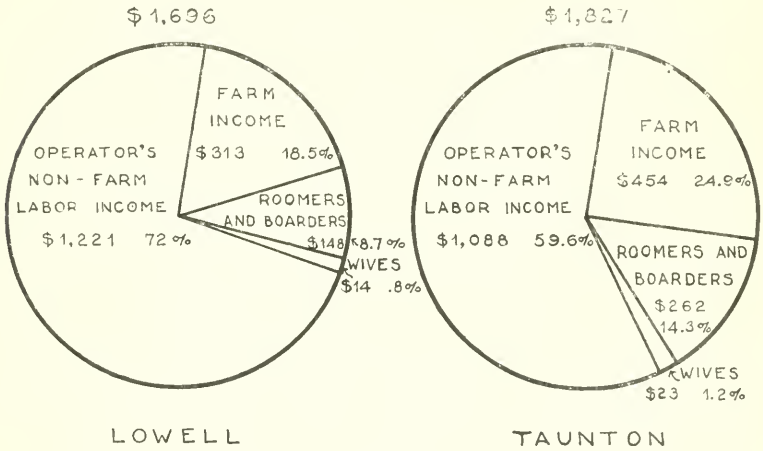
The majority of operators in both areas, as seen in Table 40, were paid between $20 and $29 per week. The average yearly wages for all operators were $1,216 in Lowell area and $1,080 in Taunton area; but for seasonal part-time farmers in the latter area, the average was only $765.

Annual Income of Operators as Derived from Each Source

In addition to the two main sources, outside employment and farming, the operators engaged in part-time farming in the areas covered by the investigation received some of their income from roomers and boarders and from the earnings of their wives.

As shown in Chart 10, the average yearly income received by part-time farmers from all sources was $1,696 in Lowell area and $1,827 in Taunton area. The most important item in both areas was the outside earnings of operators, which made up 72.0 per cent of the total annual income in the first area and 59.6 per cent in the second.

Chart 10. Percentage of Annual Income in Part-Time Farming Obtained from Each Source in Lowell and Taunton Areas.



The receipts from roomers and boarders came both from outsiders who lived in the house the whole year around or only during the summer months, and from grown-up children who had independent employment and contributed part of their income as payment for room and board. There were 47 such children in Lowell area and 59 in Taunton area.

The receipts from the earnings of wives formed the least important part in the budgets of part-time farming enterprises taken as a whole.

The wives' earnings came mainly from miscellaneous work like taking in washing, sewing, and occasionally doing some housework for the neighbors. There were, however, several wives in both areas who worked in industrial plants during some part of the year.

Marketing Methods and Problems in Part-Time Farming

Although production for sale was as a general rule of primary consideration only in seasonal part-time farming enterprises, a considerable amount of products was sold also by regular part-time farmers. The percentage of operators selling some of their products was 67 in Lowell area and 77.4 in Taunton area, and the value of products sold amounted to 36.2 per cent and 54.3 per cent, respectively, of the value of the total output of part-time farming enterprises. Judging from the fact that in the town of Holden over one-third of the total value of agricultural products sold by local producers came from part-time farming enterprises, the latter may be in some cases an important source of food supply for the market.

TABLE 41.—PRINCIPAL METHODS OF MARKETING AGRICULTURAL PRODUCTS BY PART-TIME FARMERS.

Place of sale*	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Neighbors	36	*46.8*	22	*33.8*
Stores	33	*42.9*	24	*36.9*
Dealers and buyers	6	*7.8*	16	*24.6*
Places of employment	8	*10.4*	5	*7.7*
Peddling, stands and other	11	*14.3*	5	*7.7*

*Some operators sold their products through two or more different channels.

Table 41 shows the markets through which the products of part-time farming were sold. "The neighbors", including other part-time farmers, offered the nearest market and the one used most frequently by operators in Lowell area, with stores a close second. In Taunton area these two market outlets were not used so extensively as in Lowell area; but more operators sold through city dealers or buyers, in the former area than in the latter. Other methods of marketing were employed by a few in both areas, but were of less importance.

Inasmuch as the products are sold largely on the local markets, they enter into direct competition with products supplied by regular farmers. The main difficulty in meeting the competition of part-time farming enterprises lies in the extreme irregularity of production. During a time of industrial depression with attendant slackening in employment, most of the operators begin rapidly to expand their production, and as a result the local markets become oversupplied with agricultural products. This tends to depress local prices, thus causing losses to regular farmers.

Credit Facilities and Part-Time Farming

Judging by the amount of mortgage credit used by the operators, the availability of good credit facilities is of considerable importance in the

development of part-time farming. The majority of operators, especially unskilled industrial laborers, have little chance of becoming owners of small landholdings unless they can obtain liberal credit. As shown in Table 46 (page 144), the total mortgage debt assumed by part-time farmers at the time of purchase of their property amounted to more than half of its total value. Since many operators purchased their property in an unimproved condition, they needed additional credit for effecting the necessary improvements. As a result the total mortgage indebtedness in part-time farming showed an increase in spite of the fact that many operators were paying off their original mortgages.

Mortgage credit was supplied to operators both by private individuals and by credit institutions. The Federal Land Bank provided credit in the case of only one operator. The limited utilization of this source of credit is based largely on the fact that in part-time farming enterprises the value of land constitutes only a small proportion of the total value of the property, while the Federal Land Bank loans money principally on productive farm land. Of all sources of mortgage credit to part-time farmers, the most helpful proved to be the cooperative banks which provided loans often up to 75 and 80 per cent of the valuation of the property. The repayment of mortgage debt on a monthly installment basis is another feature of cooperative bank credit which fits very well into the financial conditions of wage earners. Long-time credit on the installment plan has been provided also by real estate subdivision companies, but this source of credit proved to be very expensive to the operators.

Part-Time Farming as Affected by Farming Operations and Conditions of Industrial Employment

On the basis of available time, operators who are regularly engaged in industries can develop successfully only those types of farming which have little seasonal variation in their demand for labor. The most convenient type of farming for them is found, therefore, in small poultry and dairy enterprises. There is no season when they can leave these enterprises without some attention, but neither are there considerable periods demanding their entire time. With a given amount of family labor, the amount of farming which they can develop in these enterprises is determined largely by the working hours prevailing in the industries in which they are engaged.

In this regard the general downward trend in the number of working hours in industry is a favorable factor in encouraging the development of part-time farming. According to the recent investigation of the National Industrial Conference Board, the average number of working hours for wage earners in 25 representative industries declined from 51.5 in 1914 to 47.8 in 1927.[8] In Lowell area where almost all operators were regular part-time farmers, the average length of the working week was only 44.8 hours. This low figure was partly due, however, to slack employment, with some operators working only three or four days a week. The length of working day for the majority of the regular part-time farmers in both areas was between eight and nine hours.

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[8] Wages in the United States, 1914-1927. National Industrial Conference Board, New York. 1928.

Of almost equal importance is the time at which the operator is released from his work and is able to reach his home in the evening. He must have at his disposal some time before dark to carry on his farming operations. The introduction of daylight saving time in the State, although resented by the farming population, is a real boon to those engaged in part-time farming.

Those engaged in seasonal part-time farming are less dependent upon the length of the working day in extending their farming operations. These operations, consisting largely of the raising of vegetables and other crops, require all his working time through a part of the year, ordinarily five or six months, and leave him almost entirely free for the rest of the year unless he also keeps some live stock. His main problem is to find employment at the end of the farming season. A large industrial plant in the town of Dighton in Taunton area has provided for hiring a number of additional laborers during the winter months, thus giving employment to seasonal operators. Where no such arrangement exists, the seasonal part-time farmer, except in periods of great industrial activity, has considerable difficulty in securing temporary employment. In industrial centers like Lowell and Fall River, the manufacturing plants make no provision for utilizing the labor of seasonal operators, but depend upon a regular supply of labor. It seems, therefore, that in order to acquire greater significance seasonal part-time farming must be accompanied by a general tendency of industrial establishments to move into rural communities with a definite policy of utilizing available seasonal farm labor. The indications are that a number of factors like distribution of cheap power and good means of transportation will make for a greater decentralization of industries in the near future.[9]

The Effect of Part-Time Farming on the Bargaining Power and Employment of Operators

Although the possession of a small farming enterprise gives the industrial laborer a certain economic security, it may place him at a disadvantage by limiting his bargaining power or opportunity to find employment. For the regular part-time farmer this condition, however, is found only in the case of general business depression in the entire district in which he lives. Before the advent of the automobile and the general improvement in transportation, those engaged in part-time farming had to depend for their outside employment mostly upon the nearby village mill or some other job in the neighborhood. With better means of transportation at their disposal they can now travel greater distances to the place of work. Most of the operators in the investigated areas were employed outside of their own communities, many of them at points more than five miles from the place of their residence. Those who work in city industries ordinarily obtain the same conditions of employment as city laborers, and the fact that they are engaged in part-time farming has no effect on their bargaining power or the permanency of their employment. In small village plants, however, a tendency has been observed to pay lower wages to the operators who live in the community and are dependent upon local employment. Likewise part-time farmers who live in factory houses receive somewhat

[9] Bradford, E. S. The influence of cheap power on factory location and on farming. Ann. Amer. Acad. Polit. and Social Sci. 1925.

lower wages, but this is compensated by the lower rent they pay for the use of the company houses and land.

The operator engaged in seasonal part-time farming is more limited in the opportunities for outside employment. His bargaining power is diminished by the fact that he has to look for a temporary job, and in order to obtain it he must often make some concession in his wages. In fact, in the plants where both types of operators were employed, the wages of seasonal part-time farmers were from 10 to 20 per cent lower than those paid to the operators working the whole year round.

Housing Conditions and Costs in Part-Time Farming Enterprises

The types of houses and housing conditions vary widely in part-time farming and depend in general upon the time of settlement and original sources from which the operators obtained their landholdings. As already mentioned, some of them settled on homesteads which were previously operated as regular farms. The buildings on these holdings are as a rule old and dilapidated, and often came into possession of part-time farmers after they had housed several generations of farm families. In contrast with this, those who built their own houses lived in newer and more attractive quarters, although less spacious than the old farmhouses. Many old houses were remodeled and considerably improved in appearance after the operators moved into them. Ordinarily the work of building a new house or remodeling an old one was done by the operator himself, with occasional outside labor for the tasks where special skill was needed. Most of the construction work as well as general improvements on their landholdings was carried out gradually in spare time and as the funds for materials became available.

The average value of all houses was $2,074 in Lowell area and $2,559 in Taunton area. Almost two-thirds of all houses in both areas came within the range of values between $1,000 and $3,000. There were only two houses in each area valued at $5,000 or over. (Table 42.)

TABLE 42.—VALUE OF HOUSES.

Value of houses	Lowell area		Taunton area	
	Number	*Per cent*	*Number*	*Per cent*
Below $1000...	20	*17.4*	2	*2.4*
$1000— 1999...	39	*33.9*	22	*26.2*
2000— 2999...	33	*28.7*	30	*35.7*
3000— 3999...	12	*10.4*	22	*26.2*
4000— 4999...	9	*7.8*	6	*7.1*
5000 or over...	2	*1.8*	2	*2.4*
Total.....	**115**	*100.0*	**84**	*100.0*

The average annual cost of houses is shown in Table 43. The operators who moved into their own houses from the city seldom effected any savings in the annual cost of their rent. Most of them paid a rent in the city which was either equal to or lower than the expenses assumed in the maintenance of an owned house. The main reason for moving into the country was not so much to save on the cost of the house as to obtain better housing conditions for about the same expenditure. As may be judged from the relation between the number of rooms and the number

of persons living in them, the operators, by moving into country houses, found more spacious quarters. There was on the average a room for each person in Lowell area, and in Taunton area an average family of 5.5 persons lived in 7 rooms.

In spite of the fact that the average rent paid for rented houses in part-time farming enterprises was lower than the costs involved in owning a house, the operators as a general rule preferred to have their own houses. Most of the rented houses belonged to the manufacturing companies and were generally in good condition and given to the employees at a low rental charge. The companies ordinarily provided facilities for the employees to have small vegetable gardens and keep small flocks of poultry.

TABLE 43.—AVERAGE ANNUAL COST OF THE HOUSE.

	Houses	Persons	Rooms	Interest	Upkeep	Total cost or rent	Light	Heat	Grand Total
Lowell Area									
	No.	No.	No.						
Rented	4	6.5	6.3	....		$152	$11	$50	$213
Owned	111*	6.0	6.0	$118	$83	203	19	57	279
Total	115	6.0	6.0	..		201	19	56	277
Taunton Area									
Rented	14	4.4	6.6			$160	$13	$57	$230
Owned	70	5.8	7.1	$158	$96	254	15	67	336
Total	84	5.5	7.0	.		239	15	65	319

*One operator owned house on land held under a long-term lease.

School Facilities

School facilities for children of part-time farmers occupy an intermediate position between those available in farming districts and those in the city. Some of the part-time farming enterprises are situated in purely farming regions and are widely scattered over a large area. The majority, however, are situated in thickly settled semi-rural communities. The elementary schools are ordinarily found within walking distance of these homes. For all children of part-time farmers attending grammar school, the average distance was 1.4 miles in Lowell area and 1.2 miles in Taunton area. Nearly half the children walked to grammar school in the former and three-fourths in the latter area. All these children lived at a distance of less than one mile from the school. Those who lived at a greater distance were carried in a school bus.

The operators situated in some newly settled districts occasionally complained that the school bus did not pass by their places and the children had to walk long distances to the main road. On the whole, however, where several families settled in the more remote districts, the town authorities were prompt to extend the bus route, except for a few sections where the bad condition of the roads prevented this extension.

TABLE 44.—MEANS OF CONVEYANCE TO SCHOOL.

Means of conveyance	Lowell area				Taunton area			
	Grammar school		High school		Grammar school		High school	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
Bus	95	*46.6*	13	*43.3*	20	*19.8*	8	*61.5*
Electric car	24	*11.7*	14	*46.7*	4	*4.0*	2	*15.4*
Walking	85	*41.7*	3	*10.0*	77	*76.2*	3	*23.1*
Total	**204**	*100.0*	**30**	*100.0*	**101**	*100.0*	**13**	*100.0*

The teaching staff of all elementary schools within the areas covered by this investigation was found to be of a high standard. With few exceptions they were graduates of state normal schools, and some of them had had considerable experience in teaching.

High schools were found in only two towns in each area, and the children from the towns without high schools attended those in the nearest town or city. The average distance to high school for those who attended was 3.4 miles in Lowell area and 3.8 in Taunton area. Only 30 children in Lowell area and 13 in Taunton area were high school students at the time of the investigation. (Table 45.) Education of children of foreign-born operators, except French Canadians, ordinarily ended with the passing of the compulsory school age.

TABLE 45.—CHILDREN OF PART-TIME FARMERS.

	Lowell area		Taunton area	
	Families	Children	Families	Children
Children at home	105	440	75	274
Children under 12	61	254	57	123
Children 12 and over	76	186	55	151
Children in grammar school	81	204	53	101
Children in high school	25	30	10	13

Effect of Part-Time Farming on Health and Morale of Operators and Their Families

Of the various influences exercised by part-time farming, probably the most outstanding is its effect on the character, health and morale of operators and their families. According to the general testimony of operators, the outdoor work has proved to be of great benefit to them all. Most of the operators worked during the day in closed buildings, and while many of them performed only light tasks, they found themselves tired at the end of the day, often from the mere monotony of work around machinery.

Accordingly, a limited amount of outside work provided a desirable change of activity as well as some exercise in the fresh air. The housing in part-time farming, free from the overcrowded and unsanitary conditions of city tenements, proved also to be an important factor in creating a more healthful environment. Likewise, by consuming fresh vegetables

and other agricultural products in liberal quantities, part-time farmers and their families enjoyed a more wholesome and better balanced diet than the average city wage earner has or can afford to have.

The participation of children in farming operations and their interest in the work they were doing united the family more closely and maintained harmony between children and parents, which is often lacking among the families of city laborers. The wives seemed to be especially satisfied with the fact that their husbands were spending their spare time around the house.

The difference in economic conditions and morale of part-time farmers and city laborers is especially prominent at the time of unemployment. In addition to giving a certain return for the labor, the work in part-time farming enterprises saves the operator from the demoralization and general discouragement that presses so heavily on the industrial laborer who is left without work. While a city laborer is forced to waste his time in idleness, the part-time farmer can put his labor to productive use. Many an operator, at the time of unemployment, has brought his land into better condition by clearing it of stones and brush, made additions to his house, or otherwise improved his property.

Part-Time Farming as a Means of Saving

Ownership in part-time farming enterprises proved to be an important factor in developing habits of thrift and in increasing savings. Table 46 shows that the equity in property owned by operators in Lowell area increased from $86,383 at the time of purchase to $207,060, an increase of $120,677; and in Taunton area from $75,560 to $165,200, an increase of $89,640. The average increase in equity per operator owner was $1,138 in the first area and $1,338 in the second. It should not be assumed, however, that all these savings were effected during the period the operators owned their enterprises. Some of the increase in equity came from the savings of operators prior to their settlement on the land, and some came from the general increase in land values in the community; but most of it was due to the efforts of operators since going into part-time farming. Through the improvements gradually effected on their land and buildings, they succeeded in increasing the value of their property far in excess of additional mortgage indebtedness contracted for that purpose.

TABLE 46.—MORTGAGE INDEBTEDNESS AND EQUITY OF OPERATORS IN PART-TIME FARMING ENTERPRISES.*

	Lowell area	Taunton area
Cost of property purchased	$195,263	$157,960
Mortgage indebtedness at purchase	108,880	82,400
Equity in property	86,383	75,560
Present value of property	335,840	249,800
Present mortgage indebtedness	128,780	84,600
Present equity in property	207,060	165,200
Increase in equity	120,677	89,640
Average increase per operator	1,138	1,338

*Not counting those who were previously engaged in independent farming on the same holdings

Effects of Part-Time Farming on Community Life and Institutions

Since most part-time farmers in the areas covered by the present investigation worked outside of their communities, their interest in the local life and institutions was less pronounced than that of the regular farming population which lived and worked within the same community. Coming originally from the city and continuing often to work in its industries, the part-time farmer in many instances had his interest divided between the community he lived in and the place where he worked. As newcomers in their places of settlement, part-time farmers frequently had not yet had sufficient time to establish their roots firmly in the new place of residence and to identify themselves with local institutions. In addition, the majority of them in the areas investigated were foreign-born, in some sections having displaced the native agricultural population. In many submarginal areas, however, the land had been abandoned by the native farmers without any pressure on the part of the foreign-born operators, who came in later and began the cultivation of idle acres. This has been true in the case of most foreign-born part-time farmers in Lowell and Taunton areas.

From the standpoint of the rural communities which have witnessed a decline of their farming population, and a falling off in taxable property, the spread of part-time farming has been a desirable development. Although most of the part-time farmers could not participate actively in local institutions, they helped to maintain them through supplying increased sources for local taxation.[10]

While there was as yet only a slight participation of part-time farmers, especially foreign-born, in community affairs, this was not true of their children. By attending local schools they rapidly acquired an interest in local life and school activities and became an important factor in directing the interest of their parents to the affairs of the community.

The leadership for community life is supplied by the old residents of native stock. They take great pride in their communities and are willing to contribute their time and efforts toward improving local social conditions.

Immediate Prospects in the Development of Part-Time Farming

As already pointed out, the movement into part-time farming within the areas investigated has been especially prominent within the last decade or so. Many factors have been responsible for the decision of a large number of people engaged in various occupations to settle on the land and obtain from it part of their living. To the factors already mentioned should be added the rising cost of food distribution. Published statistics show that within recent years the percentage increase in cost of food distribution in the United States has been greater than the increase in cost of living. Many wage earners have found it profitable to satisfy their food requirements from their own farming enterprises to a considerable extent, thus eliminating the rapidly increasing cost of distribution. Nearness to consuming centers gives operators in Massachusetts

[10] For a special investigation on the effect of the settlement of industrial laborers on a rural community, see "Effects of Industrial Development on Rural Life in Sullivan County, Tennessee." University of Tennessee Record. May, 1928.

the added advantage of selling their surplus products directly to consumers, thus performing the functions of both producer and distributor.

With the present tendency to reduce further the working hours in business and industry, and with the improvement in transportation facilities, the prospects are that part-time farming will continue to increase in many sections of the country. The most important factor in fostering its development will be found in the decentralization of industries. When the industrial plants are brought from the large cities into small towns and villages, a larger number of people will find it possible to combine farming with industrial employment.

CONCLUSIONS

1. Due to the presence of a large number of part-time farming enterprises, the importance of agriculture in Massachusetts is much greater both in total output and in land area than is indicated by the Federal Census figures.

2. There are at least 60,000 farming enterprises in Massachusetts on a part-time basis.

3. Of the total number of farms in Massachusetts listed by the Federal Census, about 50 per cent are carried on on a part-time basis.

4. Part-time farming tends to develop either on land submarginal for regular agriculture or on sites important for residential purposes.

5. Developing largely on submarginal land, part-time farming does not enter into active competition with regular agriculture for the use of land.

6. At least one-third of the agricultural output in the State comes from part-time farming enterprises.

7. In communities with decadent agriculture, part-time farming helps to maintain local institutions through increasing tax receipts.

8. The development of part-time farming goes hand in hand with better transportation facilities, shorter working hours in industry, and location of industrial plants in small towns and rural communities.

9. Part-time farming secures a certain economic stability for the wage earner and provides better food and housing conditions for his family.

10. The indications are that within the next ten or twenty years part-time farming will show further development in the State.

11. In view of the important place occupied by part-time farming in Massachusetts, any agricultural program planned for the State should give increased consideration to the problems arising therefrom.

Publication of this document approved by the Commission on Administration and Finance.

4500-11-'30. No. 513

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 267 October, 1930

Hardy Woody Plants

By Frank A. Waugh and Charles H. Thompson

Hardy trees, shrubs, and vines are a very important feature of our civilization. Country roadsides and village streets are planted with trees; parks and playgrounds must have their trees and shrubs; but, most of all, the home grounds are not considered quite respectable unless trees, shrubs, and vines are used to soften and civilize the architecture and the topography. Hardy woody plants have been under study for sixty-five years on the grounds of the Massachusetts Agricultural College, and this bulletin is intended to make some of the results of these studies available.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

HARDY WOODY PLANTS

By Frank A. Waugh, Professor of Landscape Architecture and
Charles H. Thompson, Professor of Horticulture

History of Campus Plantations

The Massachusetts Agricultural College was chartered by the Legislature in 1863. The land which comprises the present central campus was bought in 1864 and turned over to college administration. Previous to this time the present central campus had been cleared of trees for farming purposes. One or two large chestnut trees which were then standing were considered landmarks, as is shown by the fact that the trustees voted to place the first important building of the college "on the western ridge near the big chestnut tree." There were, naturally, a certain number of trees, especially maple, oak and chestnut, here and there as upon any farm, but no general or decorative plantings such as are characteristic of the present campus.

Judge Henry F. French, first president of the college, evidently felt this lack of trees, and with a view to its partial correction planted a triple row of white pines along the eastern boundary (1865). These trees are now in their prime and may be seen in a splendid row running northward from Fisher Laboratory.

The earliest classes to graduate from the college believed it their duty to plant trees for the improvement of the campus. The very first class (1871) planted a row of elm trees about the circle near South College. Other classes made their contributions until the planting of class trees became a tradition. At first each class planted a considerable number of trees, often a long row. Later the classes have been satisfied with a single tree. At the present time these class plantings, many of which are identifiable by markers, cut a considerable figure, for better or sometimes for worse, in the campus furnishings.

Early Developments

The entire development of the campus received a notable impetus when Colonel William S. Clark became president in 1867. President Clark was an organizer, an enthusiast, and an inveterate tree planter. Not only did he supervise personally the planting of many trees on the campus, but he encouraged the students in this work, and also promoted the idea with his young assistant, Samuel T. Maynard of the class of 1872, who upon graduation became assistant in the department of botany and remained in actual charge of the campus development until 1902.

A special word should be said for the work done during this time. Professor Maynard also was a lover of trees and shrubs and kept up the planting from year to year. His attention was given mainly to the establishment of botanical specimens at convenient places, especially on the eastern campus, near the Durfee Plant House. His plantings were all of single specimens, never in groups. A large number of our best trees and shrubs, now in their prime, were planted by him.

It may be remarked in passing that several efforts were made during the early years of college development to secure a working plan of the campus. The most notable attempt in this direction was that of 1866, when Frederick

Law Olmsted, Sr., came to the college and gave important advice to the trustees. The main articles of his recommendations are still extant in a published report.[1] In the light of present knowledge it must be regarded as a misfortune that the trustees did not see fit to follow the recommendations of Mr. Olmsted. The development of a logical plan, however, has very little direct relation to the continued planting of trees and shrubs, and for the purposes of our present consideration may be left out of account.

Japanese Plants

Another very important chapter in the development of the grounds at Massachusetts Agricultural College is marked by Japanese influence. In 1876 President Clark went to Japan to organize the new Imperial Agricultural College at Sapporo. He remained there one year and was followed in this position by William A. Wheeler, a graduate of the college in the class of 1871. In 1877 William P. Brooks of the class of 1875 also went out to Sapporo as professor of agriculture and remained for twelve years. For several years, therefore, Massachusetts Agricultural College was represented by an active colony in northern Japan. These men, deeply interested in the new agricultural college in Amherst, kept sending back from time to time such Japanese plants as they could safely ship. Naturally the connection with the college in Sapporo continued for some time after the last Massachusetts man had returned to this country.

This correspondence resulted in the early establishment upon the campus of a considerable number of Japanese plants, especially hardy trees and shrubs. A few of the fortunate plantings of that time are still subjects of daily admiration. Notable examples are the pair of umbrella-pine trees (*Sciadopitys verticillata*) in the rhododendron garden; the splendid Japanese elm (*Ulmus japonica*) back of the President's house; fine actinidias (both *A. arguta* and *A. polygama*) on the porches at the President's house; and several good specimens of the Katsura-tree (*Cercidiphyllum japonicum*).

Recent Developments

In 1902 the general management of the campus passed into the hands of Professor Frank A. Waugh. In 1906 Kenyon L. Butterfield became president of the college and an era of building began. Along with the construction of many new buildings came other developments which necessitated some changes in the grounds, and which opened the way for new plantings. As regards the latter, the most important change was the development of foundation plantings around most of the buildings and the introduction of shrubbery mass plantings at eligible points on the campus, as about the college pond. These developments naturally gave occasion for the introduction of many new species and varieties of trees, shrubs, and vines.

About 1908 the first separate college course for the study of plant materials was undertaken by Professor E. A. White. In 1915 Professor Charles H. Thompson came to the college and made the study of plant materials his principal interest.

If anyone will exercise his imagination to generalize the campus history, here so briefly sketched, he will see that these events indicate a constantly

[1] Frederick Law Olmsted, "A Few Things to be Thought of Before Proceeding to Plan Buildings for the National Agricultural Colleges", New York, 1866.

deepening interest in campus plantations. This interest has touched both the pictorial development of the campus and the scientific study of the materials themselves. There have been progressively better identifications, better labeling and better records.

The work was not originally planned as a piece of research, though the experimental purpose was strong in many of the plantings. As time has gone on, however, the results have assumed increasing scientific importance and practical value, and it is now felt that the experience gained in the sixty-five years of work and study on this campus begins to have some substantial value. The plant notes offered in the following pages are based on the experience and records of these years, and it is hoped will be of some use to all others who are interested in hardy trees, shrubs, and vines for New England, and especially to those most directly concerned, as nurserymen, landscape architects, and all persons in charge of the development of public and private grounds.

Edaphic Conditions

The subjoined notes on species and varieties may be better interpreted perhaps with some knowledge at hand of soil and climatic factors.

The Massachusetts Agricultural College is located in the Connecticut Valley in western Massachusetts. The elevation above sealevel is 200-300 feet.

For the most part the soil is a silty loam with a tendency toward coarser, more gravelly portions. The subsoil is mainly gravel. The main campus lies on the silted bed of an extinct lake—old Lake Hadley of postglacial times. The shore of the lake traversed the campus toward one side so that while most of the plantings here reported occupy the lake bottom, others fall upon the old beach and a few stand above the ancient water line. Here the beach was formed against the side of a drumlin, also of a homogeneous gravelly character. Both drumlin and lake bottom offer, in texture and drainage qualities, exceptionally favorable conditions for tree growth. While not rich in plant foods, the soils are by no means sterile. They are remarkably easy of cultivation but inclined to suffer early from drought.

Climatic Factors

The more important climatic factors are herewith summarized from the local observer's records[2] which cover forty years from 1889 to 1928.

Air Temperature	*Normal*	*Extremes*
Highest	95.8	101, 1919
Lowest	—12.1	—26.0, 1904
Mean	47.2	
Precipitation		
Precipitation, inches	43.4	57.05, 1897; 30.68, 1908
Snow, inches	48.38	78, 1920; 24.5, 1919
Frost		
Last Frost	May 12	Apr. 23, 1904; June 3, 1908
First Frost	Sept. 19	Aug. 22, 1894; Oct. 13, 1909

[2] Gunness, Meteorological Observations, Mass. Agr. Expt. Sta. Meteorological Series. Bul. 492. Dec. 1929.

Low winter temperatures are to be specially noted, since a certain number of species (e.g. sweetgum and persimmon) find in these minimum temperatures their limiting factor. Other species which approach their northern limit in Amherst are flowering dogwood, beautybush (Callicarpa), Kentucky, coffeetree, black walnut, box, sourwood, wisteria, redbud, Paulownia, sassafras, yellow-wood, hollygrape, and filbert.

Summer drought also accounts for the failure of other species from year to year. Some of those which most clearly suffer in this respect are the firs, spruces generally, the hemlocks somewhat less, beech, yellow birch, groundselbush, Scotch broom, leatherwood, and Stephanandra.

Notes on Species and Varieties

Abies balsamea, Balsam Fir. This fine native tree is better suited to northern latitudes and cold soils. It does not do especially well on the campus nor on any similar open cultivated land. A few rather inferior specimens have been maintained but have never reached any great age or large size. An attempt to grow the balsam fir in hedge formation on light gravelly soil has been something less than a half-hearted success.

Abies concolor, White Fir. This species also prefers higher altitudes with colder, heavier soil than are found here. Nevertheless during its early years it makes an excellent growth and a very attractive symmetrical tree. If one could be satisfied with this tree for twenty years and would then be willing to dig it out and throw it away when it began to look moth-eaten, such treatment might be entirely practicable. This tree is often compared with the ordinary blue spruce to the disadvantage of the latter. Such a comparison, however, would be valid only during the youth of the white fir, when the young specimens are at their best.

Abies nordmanniana, Nordmann Fir. A fine, beautiful, dignified tree with excellent foliage. Thrives well for about twenty years, but does not make a permanently satisfactory tree in our soil and climate. During the years of its juvenile enthusiasm it is one of the most beautiful evergreens on the grounds.

Acanthopanax pentaphyllum. This fine and well-known shrub, belonging to the Aralia family, has not been honored with a "common name." It thrives, nevertheless, and is generally planted. It is stiff and somewhat thorny, growth upright, foliage bright, glossy green with five-parted leaves covering the plant from base to top. It can be used for massing and for general landscape effects. It is to be especially recommended for hedges, as it stands shearing and withstands intruders.

Acer campestre, Hedge Maple. Not quite hardy at Amherst but should be very satisfactory in a somewhat milder climate. It could be used as a large shrub or small tree, growing about twenty feet high, or it can be sheared into very fine hedges.

Acer dasycarpum, Silver Maple. (*A. saccharinum*). A common hardy tree, fast growing but subject to breakage as the wood is weak. In the Middle States, beyond the zone of the sugar maple, this species is largely used for a street tree or for general planting in parks and home grounds. It is of only secondary importance in this vicinity. The Wier maple is a half-weeping form with finely cut foliage. It makes a fairly good ornamental

specimen, though it breaks down in winter storms. At its best it has a somewhat freakish, exotic look. At one time a large number of seedlings of this Wier cutleaf maple were grown here and but a small percentage showed good cutleaf characters. The seedlings varied widely in all respects.

Acer ginnala, Amur Maple. This ought to be a very hardy species, but it has not proved so on the campus. If it were hardy and reliable it would be a good small tree or large shrub and could be recommended for shearing into hedges.

Acer japonicum, Fullmoon Maple. A few specimens of this Japanese maple have been growing on the grounds for forty years or more. Of much the same habit of growth as *Acer palmatum* varieties and may be treated like them in a planting.

Acer miyabei, Miyabe Maple. A medium-sized tree, from Japan, attaining to thirty-five feet. Branches abundantly from a short trunk, producing a large and rather open crown. Leaves much the same pattern as *A. campestre* but larger and very dark green. Suitable for mass plantings in parks or other large areas.

Acer negundo, Boxelder. Small hardy tree or large shrub of no special value. May be used in masses where foliage of coarse texture is desired. Good for low windbreaks.

Japanese Maple:

Acer palmatum atrolineare Bloodvein Maple.
Acer palmatum dissectum Threadleaf Maple
Acer palmatum ornatum Spiderleaf Maple
Acer palmatum rubrum Red Japanese Maple
Acer palmatum sanguineum Scarlet Japanese Maple
Acer palmatum septemlobum Sevenlobe Maple

All these varieties of Japanese Maples have been tested. Most of them have been growing on the college grounds for forty or fifty years. They are hardy and quite satisfactory, making strong specimens usually ten to fifteen feet tall and about the same diameter. Their bright colors make them conspicuous so that it would be possible to overemphasize them in naturalistic planting. For those who want something showy and out of the ordinary these maples would serve admirably.

Acer pennsylvanicum, Striped Maple. A hardy native species common in cold, shady woods; suitable for highly naturalistic underplanting, but not available as an "ornamental" in the accepted sense of the term.

Acer platanoides, Norway Maple. A good hardy ornamental tree, with stiff trunk and branches, thick, heavy dark foliage; good for street planting and for specimens, especially in crowded city conditions; a good shade tree for park plantings. An odd variety, the Crimped Norway Maple (*A. platanoides cucullatum*) has been growing on the grounds for forty years, but has no value except as a curiosity.

Acer platanoides rubrum, Broadleaf Norway Maple. A red-leafed variety of the foregoing, interesting only as a rare specimen.

Acer platanoides schwedleri, Schwedler Maple. A rather popular nursery variety of the Norway maple notable for its very dark red foliage in early spring, which turns a rich dark color again in the fall. The best tree of this sort, but too outspoken for modest company.

Acer pseudoplatanus, Sycamore Maple. A large coarse tree with large coarse foliage; interesting as an occasional specimen, but of no other special value; hardy and fast growing but frequently subject to a decay fungus causing large branches to break off, leaving a much deformed crown.

Acer pseudoplatanus leopoldi, Leopold Maple. A variety of the foregoing with spotted, variegated leaves which are pinkish when opening. Of no particular value.

Acer rubrum, Red Maple. A common native species, abundant in swampy land; the first maple to come into flower and foliage in spring and the first one to show color in autumn when it turns a brilliant scarlet in the swamps before any other species. Good for free planting in wet ground and for massing in natural woods. An occasional specimen or two on home grounds, especially on wet land, will not be out of place. One tree on the college grounds is sixty feet tall and of fine character and proportions.

Acer saccharum, Sugar Maple. One of the finest native trees; requires neither praise nor description. Should receive more consideration by the planting of groves as a future source of sugar.

Acer spicatum, Mountain Maple. Small undershrub, growing characteristically under hardwoods on cold, mountain land; not suitable for lawn or park planting except in its native ecological relations, but in those special conditions unsurpassed. Somewhat resembles *Viburnum acerifolium,* with which it is often associated.

Acer sieboldi, Siebold Maple. Small, rather shrubby Japanese species, introduced with other Japanese species over forty years ago. Leaves have the pattern of *A. japonicum,* but are smaller and form more densely foliaged sprays. Crown is flatter and more spreading, the branches gracefully recurving. Will work in well wherever *A. palmatum* may be used.

Actinidia arguta, Bower Actinidia. The actinidias were brought to the college from Japan about 1876 by President W. S. Clark, Professor William P. Brooks, and Mr. William Wheeler. A considerable number of seedlings were grown and tested. Many of these fruited and from time to time the fruits were tested in a culinary way. The fruit is about the size of a large gooseberry, which it resembles in some respects except that it is smooth and of a much finer flavor. These fruits make excellent jams and jellies. The vine is of greater value, however, as an ornamental climber. It is of very rampant growth and will completely overrun an ordinary porch unless severely cut back from time to time. This heading back is best accomplished during the growing season in July or August. The vines are free from disease or insect attack. They would probably be more popular except for the difficulty of propagation. They grow rather slowly from layers. Probably seed propagation, when once understood and established, would be the most expeditious method.

Actinidia polygama. Silvervine. A larger, coarser vine than *A. arguta,* and less desirable for general culture. The vines here usually show some variegated foliage. Plants are perfectly hardy. Young plants must be protected from depredation of cats. Cats have for these plants an even more violent appetite than for the familiar catnip and devour all new growths within their reach.

Aesculus glabra. Ohio Buckeye. One fine specimen of this species is

found on the campus, making a dignified tree now probably fifty years old and twenty-five feet high. Very picturesque and interesting. Some other smaller examples are also found on the grounds.

Aesculus hippocastanum, Horsechestnut. This European species is entirely hardy and satisfactory in most respects for a small-sized ornamental tree. It is better adapted to crowded city conditions than to open park work and has never been a favorite on the campus. The variety *baumanni* is represented by one good specimen. It has flowers of brighter color—rather rosy red—than the type, and fully double.

Aesculus parviflora, Bottlebrush Buckeye. A dwarf shrubby species rather interesting and worth planting. Hardy and satisfactory.

Akebia quinata, Fiveleaf Akebia. An attractive vine with fine, interesting foliage and pretty, though inconspicuous, flowers. It grows very slowly and has never made much of a show on the campus, though it has made a rampant growth in other parts of Amherst, as it does also on the Island of Nantucket. It obviously requires some time to become established. Where it thrives it is to be highly recommended as a climber for house porches, lattice fences, and similar domestic requirements.

Alnus incana, Speckled Alder. Hardy native shrub found abundantly in swampy localities.

Amelanchier canadensis, Downy Shadblow. Good, hardy native species attractive for its very early white blossoms. Quite satisfactory for planting in the borders of wild woodland.

Amelanchier oblongifolia, Thicket Shadblow. Another native species similar to the foregoing and useful in the same way.

Amelanchier ovalis, Garden Shadblow. A dwarf species also native and quite showy in border plantings. More satisfactory for use as a shrub than the preceding species.

Amorpha canescens, Leadplant. This little half-shrubby, half-herbaceous plant from the western plains has very interesting gray pinnate foliage. The flowers are dull purple and sometimes are rather pretty. The plants can be grown in very dry sunny locations. It is interesting as a curiosity but probably will not be used in any large numbers.

Amorpha fruticosa, Indigobush. A tall, leggy shrub, fifteen to twenty feet high, with pinnate foliage and abundant spikes of dark purple blossoms. It has a marked tendency to sprout from the roots and to become weedy. For planting in wild waste places it has some possible use. Hardy and not altogether unattractive.

Ampelopsis heterophylla, Porcelain Ampelopsis. A strong, hardy, climbing vine not nearly so well known as it deserves to be. It is, in fact, one of the best hardy climbers to be found. It somewhat resembles its congener the ordinary woodbine; the foliage is somewhat more like that of the grape and the berries are strikingly attractive in their many colors during ripening to a final turquoise blue; easy of propagation from seeds, cuttings, or layers; very satisfactory in all respects.

Ampelopsis quinquefolia, Virginia Creeper. This is the ordinary native woodbine, and one of the most satisfactory and most reliable climbing vines, widely used on trellis and against masonry walls. For the latter purpose

varieties should be chosen having clinging disks. This species is especially attractive for its fine autumn colors.

Ampelopsis tricuspidata, JAPANESE CREEPER. Commonly called BOSTON IVY. This is a very satisfactory climber, especially on brick, stone, or stucco walls. It thrives better on eastern and northern walls, though it can often be grown with satisfaction on western or even southern exposures. It is rather slow getting started but requires no particular care after once established.

Aralia spinosa, DEVILS-WALKINGSTICK. A big, coarse, rather showy plant, perfectly hardy and fit for use where coarse textures or striking effects are desirable. Produces abundance of small white flowers in large clusters and especially attractive in fruit.

Aristolochia sipho, DUTCHMANS-PIPE. This favorite old climber has been growing on the campus since the beginning and is entirely hardy and satisfactory. It is rather too heavy for ordinary porch use, but can be used on lattice screens and other places where support is available. It is hardy, clean, and free from insect or disease attack.

Aronia atropurpurea, PURPLE CHOKEBERRY. A dwarf native shrub rather interesting and attractive for planting along woodland borders and in other naturalistic compositions.

Aronia melanocarpa, BLACK CHOKEBERRY. Another native species similar to the foregoing and equally satisfactory for general planting.

Azalea nudiflora, PINXTERBLOOM. Sometimes also called SWAMP PINK. A beautiful native ericaceous plant suitable for the finer sorts of landscape plantings. Good nursery-grown plants are always to be recommended above native plants taken from the field.

Azalea rosea, DOWNY PINXTERBLOOM. Another of the native azaleas, preferring a somewhat drier situation than either *nudiflora* or *viscosa.* Its pink flowers with their very pleasant odor make it a valuable addition to this group of shrubs.

Azalea viscosa, SWAMP AZALEA. Somewhat similar to the foregoing and entirely satisfactory for permanent planting; somewhat more adapted to swampy, wet land.

Baccharis halimifolia, GROUNDSELBUSH. This rather insignificant native seaside shrub has been occasionally used on the grounds but has no special merit for local conditions.

Berberis thunbergi, JAPANESE BARBERRY. Extensively used on the college campus for many years for hedges, foundation plantings, and for positions requiring hardy shrubs to withstand rough use. The plant is so convenient and so thoroughly adapted to a number of diverse uses that there is always danger of vulgarizing it. Propagates readily from seed. Handles well under the shears but looks better when left to its natural habit of growth.

The variety with variegated leaves (*Berberis thunbergi variegata,* sometimes called SILVER BEAUTY BARBERRY) has also been grown on the grounds but has nothing much to recommend it.

Berberis vulgaris, EUROPEAN BARBERRY. A hardy shrub widely disseminated and to some extent naturalized throughout this region. Satisfactory for growth in the shade, for large rough hedges, and for a variety of common practical uses. Propagates readily from seed.

The Purple Barberry, a variety of the foregoing, differs from the type only in the purple color of its foliage and darker flowers; of little value for planting.

Betula alba pendula, European Weeping Birch. Several fine specimens of this popular cemetery tree formerly grew on the campus. Like nearly all other specimens of this kind they have been seriously depleted—almost completely annihilated—by the twig borer. At the present time the growing of this tree is so exceedingly difficult that it can be no longer recommended.

Betula alba pendula dalecarlica, Dalecarlia Birch. A cutleaf form of the European weeping birch which has also become almost exterminated by the twig borer.

Betula lenta, Sweet Birch. Sometimes called Black Birch. A good hardy native tree suitable for mass planting in woods but of no particular value on lawns.

Betula lutea, Yellow Birch. A hardy native tree of the wild woods, mostly at home in high altitudes and cold northern situations, often in close mixture with other hardwood and evergreen species. A striking and beautiful tree but not adapted to lawn planting or other use outside its natural ecological conditions.

Betula populifolia, Gray Birch. A common weed throughout New England, especially abundant in dry pastures and abandoned fields. This never makes a large tree but the small clumps are often picturesque and interesting. It is distinctly desirable for the development of certain naturalistic effects in park planting. It prefers an acid soil.

Bignonia radicans, Trumpetcreeper. A strong-growing, vigorous, hardy, coarse climbing vine, with striking yellow or orange blossoms, suitable for growing over rustic trellises, outbuildings, or in other positions where a coarse rampant-growing vine is desired.

Buddleia davidi, Orange-eye Butterflybush. A small shrub valuable in milder climates but not quite hardy on the college campus.

Buxus sempervirens, Common Box. Not safely hardy at Amherst, though occasional specimens are found in the neighborhood where given special protection. Plants which from time to time have been set on the college grounds have all disappeared, weakened by red spider and killed by hard winters.

Buxus sempervirens suffruticosa, Truedwarf Box. This variety is thought to be hardier than the species. About two hundred plants were set as a garden edging on the grounds five years ago from which not a plant has been lost. They have been given light winter protection, however.

Callicarpa purpurea, Chinese Beautyberry. This shrub has been tested for a number of years on the college campus and has proved to be not quite hardy. It kills back nearly every winter and sometimes severely. It is rather an attractive shrub when growing well, the turquoise blue berries being especially interesting.

Calycanthus fertilis, Smooth Sweetshrub. A good coarse-leaved shrub suitable for border planting. The dark maroon-colored flowers are pleasing but not conspicuous. Flowers of this particular species lack the strong aromatic fragrance of other species of the same genus.

Caragana arborescens, Siberian Pea-tree. A tall shrub sometimes reaching

the proportions of a small tree. Very hardy against cold and drought, but not especially adapted to this soil and climate. It makes an admirable hedge in some localities and will bear shearing well. It also makes fairly good specimens. On the whole it cannot be very highly recommended on the basis of its performance on the campus.

Castanea pumila, CHINQUAPIN. An attractive shrub of open growth sometimes bearing very toothsome edible nuts. Suitable for plantings in wild gardens.

Catalpa bignonioides, COMMON CATALPA. A medium-sized tree with coarse, broad foliage and attractive flowers. The catalpas are not entirely hardy on the campus and for this reason not wholly satisfactory. This species is less symmetrical in form and less hardy than *C. speciosa*.

Catalpa speciosa, WESTERN CATALPA. A medium-sized tree with large, coarse foliage and large, quite showy flowers borne in abundance in midsummer. If this were not inclined to look shabby and threadbare, due to insufficient hardiness, it would be an attractive lawn tree. It is worth keeping in a large collection even with its disadvantages.

Ceanothus americanus, JERSEY-TEA. A hardy native shrub, small, with good foliage and attractive creamy-white flowers. Suitable for moderately dry, exposed situations and may be recommended for frequent planting in such places.

Celastrus orbiculatus, ORIENTAL BITTERSWEET. This species has been extensively used on the college campus and is thoroughly satisfactory. The habit of growth is rather better than that of the native bittersweet. Fruits are produced in greater abundance but are scattered and in small clusters, and are less conspicuously decorative. This does fairly well on the shady side of buildings and may be used in almost any circumstances where a climbing vine is desired, such as on residence porches, etc.

Celastrus scandens, AMERICAN BITTERSWEET. This fine, hardy, native climber is one of the best in the whole list and should be given preference in many locations, as house porches and domestic buildings generally. It will stand considerable shade, is very hardy, and the fruits, produced in large clusters at the ends of the season's growth, are highly ornamental.

Celtis occidentalis, HACKBERRY. One good large specimen of considerable age—approximately fifty years—has represented this species on the campus along with a few smaller, younger plants. There is nothing striking or especially valuable about this western tree, although it may be grown as an interesting curiosity.

Cephalanthus occidentalis, COMMON BUTTONBUSH. A hardy native shrub growing in the borders of ponds and swamps. Rather a good shrub for general planting in such situations. Requires no special care.

Cercidiphyllum japonicum, KATSURA-TREE. This Japanese tree was early introduced into Amherst and to the Agricultural College campus and a number of excellent specimens of approximately fifty years of age are under observation. The tree is shapely and attractive with beautiful clean foliage but usually begins to deteriorate after forty years of age. It is an attractive tree for specimen planting on grounds of moderate size and would always be worth including in a park collection.

Cercis canadensis, American Redbud. This species is hardy here and its brilliant blossoms in early spring are acceptable. It does not thrive with the same exuberance which one sees along the water courses of the Central States.

Cercis chinensis, Chinese Redbud. This species has also been tried on the college campus but has gone out. It appears not to be hardy.

Chamaecyparis obtusa, Hinoki Cypress. Trees of this genus considerably resembling the American arborvitae, have been planted quite extensively on the college campus. They seem to be entirely hardy and satisfactory. The texture is somewhat finer than with the usual arborvitae and there are differences in color and habit of growth which are interesting. They should always be included in any collection of coniferous trees in this part of the country. This particular species resembles the arborvitae more than some of the others. Its foliage is a darker green and glossy and in more compact sprays.

Chamaecyparis pisifera, Sawara Retinospora. A good, hardy, interesting species of this important genus.

Chamaecyparis pisifera filifera, Thread Retinospora. The odd and interesting foliage of this variety makes it desirable in a collection.

Chamaecyparis pisifera plumosa, Plume Retinospora. This variety has a bluish cast of foliage and a striking fine texture which make it more showy than most of the other varieties. On this account it may be either more or less desirable, according to the local requirements or one's point of view.

Chamaecyparis pisifera plumosa aurea, Goldenplume Retinospora. There is always a demand for showy, bright-colored, golden-hued evergreens, and this variety satisfies that desire measurably. It is also perfectly hardy and satisfactory otherwise.

Chamaecyparis pisifera squarrosa, Moss Retinospora. This variety has silver-gray foliage of very attractive character. For any tree off-color this is about as satisfactory as could be wished.

Chamaecyparis thyoides, Whitecedar. This species is not well represented on the campus, but seems to be as fully available as other examples of the same genus.

Chamaedaphue calyculata, Leatherleaf. A small-leaf native evergreen of low growth, found growing in bogs. The flowers much resemble those of blueberry and are borne suspended from the lower side of the spreading branches. May be used with good effect in a moist situation but is of little value elsewhere.

Chionanthus retusa, Chinese Fringetree. This little-known shrub has been growing on the campus for at least forty years and has proved itself perfectly hardy. In habit of growth and foliage it differs little from the native *C. virginica.* The flower clusters are somewhat denser and appear a little later than in that species. The large clusters of purple fruit in the fall are an added attraction for a time, but are soon devoured by birds.

Chionanthus virginica, White Fringetree. This native species makes a strong large shrub sometimes reaching a height of twenty feet. It is rather coarse and thick in growth without any especially desirable qualities except a fine showing of white flowers in May. At the flowering season it is quite striking and satisfactory.

Cladrastis lutea, Yellow-wood. A fine, interesting tree native in the states

farther south and not quite hardy here. Beautiful in foliage and especially beautiful in flower. Would be very satisfactory for park and lawn planting except for its tenderness to the climate.

Clematis grata grandidentata, Himalayan Clematis. One specimen of this species has been growing on the campus for nearly thirty years and is greatly admired. It is of moderate growth, good foliage, and bears abundant white flowers somewhat resembling the ordinary virgins-bower. Considered here as one of the best of all clematises. This species has been propagated here by hardwood cutting and layers. It does not reproduce easily.

Clematis heracleaefolia davidiana, Fragrant Tube Clematis. This species was rather generally recommended by nurserymen a few years ago, and is indeed attractive, something between a shrub and a climber in habit, perhaps best suited to large effects in rock gardens. It has not proved hardy on the campus—in fact, is extinct here.

Clethra alnifolia, Summersweet. This native small shrub is best adapted to plantings in moist situations though it will thrive less luxuriantly in dryer locations. It is suitable for wild plantings. Its most striking feature is the production of abundant flowers in late summer, at a time when few other shrubs are in bloom. The flowers are pleasantly fragrant and are excellent nectar flowers for the apiary.

Clethra tomentosa, Woolly Clethra. This southern species is perfectly hardy and grows readily on the college grounds, though not a very tidy or attractive shrub. It is suitable for wild plantings, especially in moist localities. Its flowering habit is like that of *C. alnifolia.*

Comptonia asplenifolia. Sweetfern. This hardy, native, well-known shrub has been grown to some extent on the campus. It transplants with great difficulty; otherwise it would be very satisfactory for certain situations in park use, especially for dry, hot, sterile soil.

Cornus alba sibirica, Coral Dogwood. A hardy, strong-growing, upright dogwood with red branches. Very satisfactory for borders and wild garden effects.

Cornus alternifolia, Pagoda Dogwood. A large, strong, upright-growing native species suitable for woodland planting and woodland borders.

Cornus amomum, Silky Dogwood. One of the most common native dogwoods, growing in moist situations, frequently accompanying *stolonifera.* Its bright blue fruits and dark red stems give it added values in autumn and winter.

Cornus florida, Flowering Dogwood. Geographically the northern range of this species runs a little beyond Amherst. Even in this locality the species begins to show the stress of nonadaptation to the cold winters. Nevertheless it usually flowers in the spring and is always welcome. It is too good a species to be overlooked in any extensive planting.

Cornus florida pendula, Weeping Dogwood. A weeping variety of ordinary flowering dogwood; curious but of no particular value.

Cornus florida rubra, Redflowering Dogwood. Considerable variations in the color of flowers occur in this species in nature, varieties with more or less pink or reddish blossoms being not especially uncommon. The variety propagated by the nurserymen under this name is genuine and practically satis-

factory. The variety is, in fact, quite attractive and well worth using in reasonably large numbers in any considerable plantation.

Cornus kousa, Kousa Dogwood. This Japanese species is of comparatively recent introduction and is said to be more hardy than the native *Cornus florida*. Experience here thus far does not bear out such a statement. The oldest plants, about ten years on the ground, have seemed to be less floriferous than the native species. The flowers are somewhat smaller but quite attractive, and the species is worth using in a collection, but could not be recommended as a substitute in any way for the native *Cornus florida*.

Cornus mas, Cornelian-cherry. This old-world species has proved perfectly hardy. Its very open crown and tendency to legginess do not commend it for general planting, though it may be used to advantage in the background of a shrubbery. Its mass of small golden-yellow flowers, preceding the leaves, makes it a cheering harbinger of opening spring.

Cornus paniculata, Gray Dogwood. This is one of the hardy native roadside species and while it has no conspicuous ornamental characters it is very satisfactory for mass planting and much general landscape work. In fact it is one of the most solidly useful shrubs for general park planting in the entire genus. The clusters of white fruits on pink stems are attractive for a short time and are greedily devoured by birds.

Cornus stolonifera, Red-osier Dogwood. This hardy native species is most frequently found in wet land beside ponds and water courses. It is a good thrifty species quite satisfactory for planting in moist situations. The bark is bright and attractive in its winter condition. This species seems to be frequently confused with others, e. g. *C. alba sibirica*, *C. alba*, and even *C. amomum*.

Corylus americana, American Hazelnut. A hardy native species found along the woodland borders. A good, thrifty plant for rough border plantings but without any distinctive ornamental characters.

Corylus avellana, Filbert. The filbert, or European hazelnut, is sometimes found in nursery collections. It is a larger, stronger-growing plant than the American species and more effective for general planting. Otherwise it has no superiority. This species has a purple-leaved variety known as *Corylus avellana atropurpurea*, the Purple Filbert. It is one of those showy purple-red leaved forms quite conspicuous in the spring season, but not to be recommended for general use.

Crataegus monogyna, English Hawthorn. The English hawthorn is perfectly at home on our grounds and thrives consistently on any well-drained soil. It is hardy and satisfactory. It blossoms well each spring. As a specimen plant it is distinctly less attractive than many of the native species. In England the hawthorns, this species especially, are famous for use in hedgerows. In America they seem to be less satisfactory as hedges than several other species of other genera.

Crataegus oxyacantha bicolor, Redrim Hawthorn. One of the brightly colored varieties of the English hawthorn. Except for the flowers it has the same characters as the parent species.

Crataegus oxyacantha pauli, Paul English Hawthorn. Another variety of the English species having little difference except in the flowers, which are rosy red and fully double.

Cydonia japonica, Flowering Quince. A sturdy, fine, hardy, shrub with beautiful flowers in various colors, mostly red or orange, but sometimes white. These selected colors may be purchased from the nurserymen. This makes an attractive specimen on the grounds, is excellent in foundation plantings, and on good well-drained soil makes a fine hedge. A few years ago it was threatened with extinction from attacks of San Jose scale, but with the subsidence of this pest it is coming back into favor.

Cytisus scoparius, Scotch Broom. An interesting plant with slender, upright, very dark green stems and fine foliage and with bright yellow flowers in early spring. Not fully hardy here, being badly killed back in severe winters. Along the seacoast it is quite extensively used and seems to be more at home there.

Deutzia gracilis, Slender Deutzia. One of the best-known species in this fine genus. A splendid, small, hardy, clean, thrifty shrub with good foliage and especially beautiful flowers, excelled only by the following species.

Deutzia lemoinei, Lemoine Deutzia. Much like the foregoing. Said to be a hybrid but more floriferous than the usual species, the flowers being very abundant, clear waxy white. This should be included in every list of ornamental shrubs, no matter how small.

Deutzia scabra, Fuzzy Deutzia. A tall-growing (ten to twelve feet) rather coarse, upright shrub, with flowers white or pinkish. Not quite so hardy as the other deutzias and not so attractive to the ordinary eye. It is not common in cultivation. The variety *Deutzia scabra plena,* Pride of Rochester is the best form of this species and is available from most nurseries.

Diervilla trifida, Dwarf Bush-honeysuckle. A small native plant not at all conspicuous but rather pretty in its proper place on the shady borders of woods.

Diospyros virginiana, Common Persimmon. This species has been planted several times on the college campus but does not seem to be permanent. It is of no special ornamental value and being doubtfully hardy at this station should not be recommended.

Dirca palustris, Leatherwood. A fine and interesting native species. A hardy, slow-growing shrub, rather attractive in blossom and of good foliage. This should be included in any collection of hardy native shrubs and would be valuable for general planting except for its slow growth and rather difficult propagation. It prefers a moist soil and will not tolerate extreme drought.

Elaeagnus angustifolia, Russian-olive. A tall-growing, open, and irregular shrub, much resembling a gray-foliaged willow. Though perfectly hardy it has not proved of particular value here. It appears to prefer a moist soil location.

Elaeagnus longipes, Cherry Elaeagnus. A good hardy shrub from Russia, attractive in habit of growth and foliage, also in fruit, the fruits being edible though not of high quality. This is a good reliable shrub and worth using.

Elaeagnus umbellata, Autumn Elaeagnus. Somewhat similar to the foregoing and having the same good qualities. The foliage more silvery-white. The small, bright red fruits, much resembling red currants, are produced in bunches and in great quantity and their long persistence makes the plant a striking feature in autumn.

Enkianthus perulatus, White Enkianthus. This Japanese shrub has been growing on the campus for four years and has withstood all the weather changes of that period, giving good promise of perfect hardiness. It is a very attractive plant in foliage and in flower and worthy a place in border plantings.

Euonymus alatus, Winged Euonymus. This is really a splendid shrub of good foliage and habit of growth. While the fruit is not so conspicuous and attractive as in some of the other species in this group, the plant as a whole is one of the best. It is good for specimen planting, also as a large figure in foundation plantings, and prunes easily to make a splendid hedge. Its characteristic winged twigs and branches make it a striking plant in winter. It should be much more extensively used.

Euonymus radicans, Wintercreeper. A very hardy, small, shrubby, evergreen vine of many uses: suitable for covering banks and bare spots either in shade or sun; interesting on fences, stone walls, and the sides of old buildings. Often satisfactory against brick walls where a tall, fast-growing creeper is not desired. Variegated specimens are often seen and sometimes propagated, but they are less attractive than the pure green species.

Euonymus radicans vegetus, Bigleaf Wintercreeper. The foliage of this variety is much larger and thicker than that of the species. It is also smoother and more shining dark green. The variety grows more rapidly and can be used as a clinging vine against brick, stone, or wooden buildings, reaching even to considerable height. In general it is very hardy, beautiful, and satisfactory. Its clusters of ripe fruits, combining red and white, contribute materially to its beauty in autumn.

Exochorda grandiflora, Common Pearlbush. A large shrub, quite compact and well formed when not crowded. The light gray-green foliage gives a pleasing contrast in a mixed shrubbery. The clusters of pure white, rather large flowers are a decided attraction during their season.

Fagus americana, American Beech. This hardy native tree is always attractive in woodland, but being difficult to transplant is not much used by landscape architects and park superintendents. It seems to be really worthy of more attention.

Fagus sylvatica, European Beech. Several varieties of the European beech have been grown here, viz. *Fagus sylvatica incisa,* Cutleaf Beech; *Fagus sylvatica purpurea,* Purple Beech; *Fagus sylvatica riversi,* Rivers Beech. These are all thrifty and satisfactory, the cutleaf beech especially so. For plants of freaky character these are singularly beautiful and unobjectionable.

Forsythia intermedia, Border Forsythia. A fine, upright, hardy shrub, greenish twigs, good foliage, and abundant bright yellow flowers early in spring. One of the standard species for general mass planting.

Forsythia suspensa, Weeping Forsythia. A rambling, creeping, pendant shrub often growing thirty or forty feet long with a height of six or eight feet from the ground; foliage good and flowers attractive. This species is especially satisfactory for covering banks and waste land.

Forysthia suspensa fortunei, Fortune Forsythia. A foliage variety apparently less valuable than the ordinary species.

Forsythia viridissima, Greenstem Forsythia. Much like *Forsythia intermedia* except that the stems are coarser and brighter green and the elongated

foliage somewhat more abundant. This is a very good species and one fit for general use.

Fraxinus americana, White Ash. A hardy native tree often making splendid boles with a dignified outline of head and good foliage; a good timber tree; will stand some shade and prefers rather moist land; is sometimes used for street tree planting but is better in mixed woods where its value should never be overlooked.

Fraxinus lanceolata, Green Ash. Another native species suitable for uses similar to the foregoing except that it has a still stronger preference for moist land. More common in cultivation because of its more ready propagation from seeds.

Fraxinus pennsylvanica, Red Ash. A large tree with most of the characters of *Fraxinus lanceolata* but less attractive and not so well adapted to this region.

Ginkgo biloba, Maidenhair-tree. This fine Japanese species has been long established on the college grounds and has shown itself well adapted to this climate. It has now become rather well known throughout the country and is something more than an interesting curiosity.

Gleditsia triacanthos, Common Honeylocust. When well grown this species makes a fine, dignified tree. On this campus it has never done exceptionally well. In fact there are indications that it is not quite hardy here. The tree is very thorny and is sometimes used for hedges. It has been tested in the demonstration hedge garden, but the results would not commend themselves to most persons. There is a thornless variety of this species called *Gleditsia triacanthos inermis* which would naturally be chosen in preference to the very thorny species.

Gymnoclados dioica, Kentucky Coffeetree. A fine, attractive tree in its native habitat in the Central States but not quite hardy here. A good specimen about thirty years old was killed to the ground by the hard winter of 1917-18.

Halesia tetraptera, Great Silverbell. A large shrub or small tree from the South Central States; somewhat awkward and leggy and without much to recommend it except the beautiful flowers. These are really very fine.

Hamamelis virginiana, Common Witch-Hazel. A fine, hardy, native species especially interesting because of its yellow flowers borne late in November and December, after the falling of the leaves. However, the shrub is interesting and worth while for its habit of growth and its foliage. It is somewhat slow of growth but worth using in mass plantations, especially along woodland borders and for underplanting in open woods.

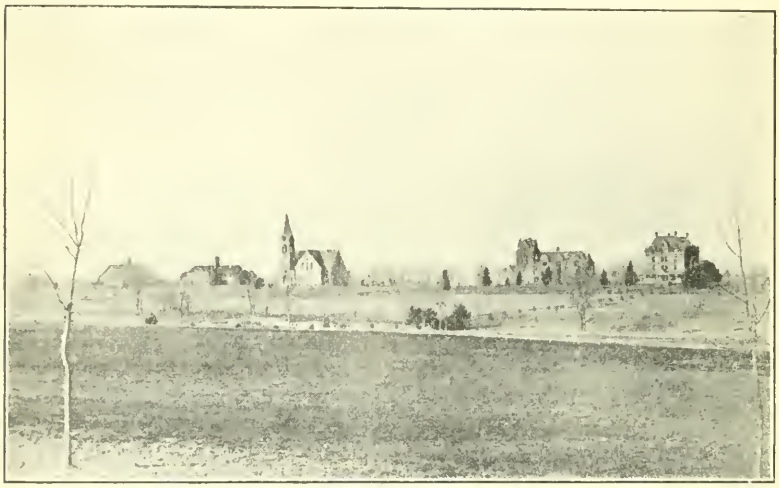
Hedera helix, English Ivy. This species is not entirely hardy in Amherst. If given considerable protection it can be kept along from year to year but should not be chosen for regular practical use.

Hibiscus syriacus, Shrub-althea. This shrub is interesting mainly for its large showy flowers, and the fact that they are produced at a time when few other shrubs are in blossom. It is not altogether hardy here and has the further objection that it comes out very late in spring and drops its leaves very early in autumn. Along the seacoast the species does much better. Here it is to be recommended mainly as an interesting addition to a collection.

Hicoria ovata, Shagbark Hickory. A splendid native tree hard to propagate, hard to transplant, and of very slow growth. Nevertheless the tree is so fine in all its characters that it is worth using, especially on large, open lawns, or for broad park effects.

Hydrangea arborescens grandiflora, Snowhill Hydrangea. This is probably the best of the hydrangeas for this section of the country. It has large and abundant clusters of good white flowers, the foliage is clean, and the general effect, while coarse, is rather good. The plant thrives well and does its best if cut back to the ground every year or every other year.

Early View of the College Campus About 1889.



Hydrangea paniculata grandiflora, Peegee Hydrangea. A very common, well-known, popular shrub with large clusters of coarse white flowers, perfectly hardy and of easy culture. It should be pruned back rather heavily each year in order to get best results. The type species, *Hydrangea paniculata*, has a more open flowering truss, and the flowers, though less conspicuous, are more graceful. In many situations it is to be desired to the more popular Peegee hydrangea.

Hydrangea petiolaris, Climbing Hydrangea. This species has long been growing on the college grounds and does very well. It may be freely recommended as a first-class climbing vine for covering walls. This is another of the noteworthy introductions of President Clark. The late Professor Sargent was authority for the statement that the plant now growing on the elm tree on the Clark estate, college campus, was the first plant of the species that came to America.

Hypericum aureum, Golden St. Johnswort. An attractive shrub with bright leaves and shiny, golden-yellow flowers. First rate for foundation plantings and small work generally.

Ilex glabra, INKBERRY. This rather compact evergreen shrub, native to Cape Cod and adjacent regions, has been growing on the campus for the past few years and gives promise of perfect hardiness here. Plants growing on the south side of spruces which give some winter protection thrive better than those in full exposure.

Ilex opaca, AMERICAN HOLLY. A good native species common along the seaboard but not often planted in this neighborhood. It is not entirely hardy here. The foliage is good and the species promises to be of considerable value in general landscape architecture.

Recent View of the College Campus Showing the Development of Tree Plantings.

Ilex verticillata, COMMON WINTERBERRY. A very hardy native shrub most commonly found in swampy or wet ground and remarkable for its beautiful, bright red berries, which are held late in the winter after the deciduous leaves have fallen. Quite common and popular under the misnomer "black alder." It is not difficult to transplant and may be freely recommended for use in suitable moist land.

Juglans cinerea, BUTTERNUT. A native timber tree of no particular value. The tree is awkward and sprawling in growth, nearly always showing a considerable amount of dead wood. It is suitable for planting in native wood compositions, but hardly for use in lawns.

Juglans mandshurica, MANCHURIAN WALNUT. A large, spreading walnut tree with good foliage. The specimen on the campus bears nuts abundantly. This is possibly the best of the oriental walnuts for use in this section.

Juglans nigra, BLACK WALNUT. This species is slightly out of its range at Amherst. Trees have been growing on the college campus for many years but they do not thrive. One walnut tree is known in this neighborhood, however, which has attained considerable size and which habitually bears fruit. The species is not to be recommended for general planting.

Juglans regia, Persian Walnut. This species is not quite hardy and has never shown sufficient aptitude for this climate to be recommended.

Juglans sieboldiana, Japanese Walnut. Hardy and quite satisfactory. Makes a large, spreading, fairly dignified tree and usually produces an abundant crop of tasty nuts.

Juniperus chinensis, Chinese Juniper. Mature trees reach a height of sixty feet and are more or less of pyramid form and have bluish-white foliage. Plants on the college grounds are still small but in the five years trial have proven perfectly hardy. This species is more commonly met with in the following variety.

Juniperus chinensis pfitzeriana, Pfitzer Juniper. Has been used to some extent in foundation plantings on the college campus. Seems to be hardy and satisfactory. A showy, small, low-spreading, ornamental evergreen.

Juniperus communis suecica, Swedish Juniper. An interesting dwarf columnar evergreen suitable for foundation plantings and fancy work generally. Perfectly hardy.

Juniperus sabina, Savin Juniper. Another hardy, rather dwarf evergreen suitable for ornamental plantings, foundation plantings, etc.

Juniperus virginiana, Redcedar. This species is native and abundant in the neighborhood. It is hardy and permanent. It can be used for certain formal effects if care is taken in the choice of specimens. However, in such locations it usually seems necessary to replace the specimens after a few years. Specimens may be sheared to advantage. This species should be planted in dry, warm, sunny situations.

Kalmia angustifolia, Lambkill. A dwarf native laurel very common and very hardy on waste land. Of no particular horticultural value.

Kalmia latifolia, Mountain-laurel. This hardy native evergreen shrub with its beautiful waxy flowers is very popular. It has been used in small quantities in plantings on the college grounds. Moderate success is possible by transplanting small plants from the woods very early in spring. Very much better results are to be had from obtaining good stock (balled and burlapped) from the nursery.

Kerria japonica, Kerria. A tidy and delightful small shrub remarkable for its bright green stems and foliage. The stems make an attractive winter effect. The plant is perfectly hardy here except that the tips of the shoots usually show some winterkilling. These ought to be snipped off early each spring, after which the plant takes care of itself admirably. A very desirable shrub for general planting.

A colored variety of the foregoing is the Silver Kerria (*Kerria japonica argenteo-variegata*). This is merely a sickly looking form of the species and not nearly so good.

Another garden form is the Double Kerria (*Kerria japonica flore-pleno*). The double yellow flowers are rather attractive; otherwise this variety is inferior to the type.

Koelreuteria paniculata, Goldenrain-tree. A rather attractive small tree with somewhat irregular and picturesque growth, pinnate leaves, and fine trusses of yellow flowers. It is hardy, permanent, and desirable.

Laburnum vulgare, Goldenchain. This small tree is very fine with its long

trusses of yellow blossoms when they can be secured. Unfortunately it is not hardy and reliable in this climate. Appears well adapted to the more uniform climate of the coastal regions.

Larix europaea, European Larch. Has been rather extensively planted on the college grounds mainly as woods rather than as separate ornamental trees. It has some timber value and is a rather attractive tree in itself. Quite hardy and permanent.

Larix leptolepis, Japanese Larch. A fairly good tree but more straggling and less symmetrical than the European larch. Worth growing as an occasional specimen.

Leucothoe catesbaei, Drooping Leucothoe. A hardy subshrub with interesting festoons of glossy evergreen leaves; blossoms inconspicuous. Excellent for foundation plantings and especially appropriate when associated with rhododendron, kalmias, and pieris.

Ligustrum amurense, Amur Privet. The hardiest and one of the best privets for general use in this section. Like all the privets this does comparatively well in shade. It is easily pruned and makes a good hedge.

Ligustrum ibota, Ibota Privet. A Japanese species widely used in ornamental planting, hardy and clean. The bush is more spreading and graceful than most other species and is therefore more satisfactory for informal planting. However, it submits well to pruning and is fairly satisfactory in hedge form. The abundance of persisting purple-black fruits give it value for winter effects, and these fruits are attractive to birds.

Ligustrum ibota regelianum. Regel Privet. A variety having somewhat the same characteristics as the species but a little more sprawling in growth, and somewhat lower.

Ligustrum ovalifolium, California Privet. Has been repeatedly planted on the college campus and sometimes lives for a few years, but eventually is always winterkilled. This species, much used farther south, is thoroughly unreliable in our latitude.

Ligustrum vulgare, European Privet. This species has been frequently planted on the campus and was formerly a great favorite throughout this section. It is, however, somewhat subject to disease and has now been almost completely replaced by Amur Privet.

Ligustrum vulgare lodense, Dwarf Privet. A very dwarf variety somewhat rare in the nursery trade. Has been growing on the campus for five years but is quite uncertain. Plants are irregular in size and hard to establish.

Liquidambar styraciflua, Sweetgum. Has been repeatedly planted on the campus and continues from year to year though obviously not well adapted to the climate. Not to be recommended for general planting in this latitude.

Liriodendron tulipifera, Tuliptree. A large fine tree, somewhat out of its latitude here but fairly hardy. On account of its attractive showy flowers rather desirable. An occasional specimen will do very well, but at Amherst and in higher altitudes it should not be relied upon.

Lonicera bella, Belle Honeysuckle. A hybrid of *L. morrowi* and *L. tatarica* partaking of more characters of the latter parent but inferior to both. Though perfectly hardy, its use is not recommended.

Lonicera dioica, Limber Honeysuckle. A native climber with whitish leaves and greenish-yellow flowers. Of no particular value as an ornamental.

Lonicera japonica, Japanese Honeysuckle. A rather densely growing vine with abundance of dark green foliage. It characteristically branches freely from the ground up, thus making an excellent screen when trained on a trellis. Its pleasantly fragrant flowers give added value. It is more commonly met with in the variety *halliana*, which usually produces a greater abundance of flowers.

Lonicera maacki, Amur Honeysuckle. A vigorous, upright-spready, lusty shrub, with clean foliage, flowers inconspicuous for this genus, fruits dark red and showy. A good large shrub for general use.

Lonicera morrowi, Morrow Honeysuckle. A big, lusty, strong, spreading, thickly branching shrub with good foliage and attractive creamy-yellow flowers, followed by bright red or orange fruit. One of the best of all the honeysuckles for general landscape use.

Lonicera ruprechtiana, Manchurian Honeysuckle. This is another of the taller-growing shrubby species with much of the habit of growth of *L. tatarica* and *L. bella*. Though perfectly hardy it shows no special features which would recommend it for general planting.

Lonicera tatarica, Tatarian Honeysuckle. A well-known species quite widely used for ornamental planting. Plant rather upright and coarse, with attractive pink or white flowers. It has also been tried in hedge formation but does not stand shearing well. Best suited to a background in a shrubbery border. The abundant bright red fruits are very attractive in the autumn and are lures for many birds.

Lonicera xylosteum, European Fly Honeysuckle. A fine, strong species closely resembling *L. morrowi*, but of taller growth. Hardy and worth common planting.

Lycium chinense, Chinese Matrimony-vine. A strong, lusty, hardy, thick-growing shrub with long recurving branches, highly suited to growing over outbuildings, on rustic trellises, or on banks and ledges. One of the best in its class.

Lyonia ligustrina, He-huckleberry. A small shrub of no practical importance.

Magnolia acuminata, Cucumbertree. A large, coarse-growing tree with stiff stems, large, coarse foliage, and medium-sized greenish-yellow flowers. Not quite hardy here and not sufficiently attractive to be recommended.

Magnolia conspicua, Yulan. A large, coarse-growing tree with coarse foliage and large showy flowers. Sometimes kills back in hard winter weather. Not especially valuable.

Magnolia cordata, Yellow Cucumbertree. Somewhat similar to the *M. acuminata*, of which it is considered only a variety by some authors, differing primarily in having smaller leaves and flowers.

Magnolia glauca, Sweetbay. A small tree which does not seem to be hardy in our locality. Better suited to the coast regions.

Magnolia hypoleuca, Silver Magnolia. A strong, upright-growing tree with large, coarse-growing foliage, not yet sufficiently tested on the college campus.

Magnolia soulangeana, Saucer Magnolia. This hybrid between a tree and a shrub, both natives of Japan, is represented by many intermediate forms between those of the parents, a number of which are perfectly hardy here. It is probably the best magnolia for general planting in this section. It bears abundant blossoms every year, which are large and attractive, ranging in color from white to purple. Two varieties of this hybrid which have done well on the campus are Lenne Magnolia (*M. soulangeana lennei*) with large purple flowers, and the Large Saucer Magnolia (*M. soulangeana alba superba*), both interesting novelties.

Magnolia stellata, Star Magnolia. A small shrub very attractive for lawn planting. The beautiful white flowers appear quite early in spring. Unfortunately the species does not seem to be entirely hardy here. Successive plantings last for a few years but finally disappear.

Magnolia tripetala, Umbrella Magnolia. A coarse, open-headed tree of no special value. It very much resembles the Silver Magnolia (*M. hypoleuca*) and is of about equal value with it as a plant material.

Mahonia aquifolium, Oregon Hollygrape. An evergreen shrub having distinctly ornamental qualities. It is, however, hardy only near the seashore or, in Amherst, in protected positions.

Malus baccata, Siberian Crab. Very hardy ornamental crab, making a good tree with rather thick head. Quite satisfactory for park and lawn plantings.

Malus coronaria, Wild Sweet Crab. A species native to the Middle West and one of the very best. This is usually quite hardy but has sometimes suffered in severe winters.

Malus floribunda, Japanese Flowering Crab. One of the fine, hardy, dwarf flowering crabs from eastern Asia, flowers very dark red and abundant. The very attractive small fruits persist for some time. Apparently hardy and permanent and growing in popularity. Hybrids of which this species is one of the parents are represented on the campus by *M. arnoldiana*, Arnold Crab, and *M. scheideckeri*, Scheidecker Crab.

Malus halliana parkmani, Parkman Crab. Of much the same habit as *M. floribunda* but more dwarf and the flowers are half double. A hybrid kin to this species is *M. atrosanguinea*.

Malus ioensis plena, Bechtel Crab. This double-flowered variety of a species native to our Middle West is deservedly growing in popularity. It makes a well-rounded small tree and produces its large, pink roselike flowers in abundance. It proves to be perfectly hardy here.

Morus alba, White Mulberry. This makes a small tree with rather loose open head, of no special ornamental value but useful mainly because the fruit is very highly regarded by birds.

Morus alba tatarica, Russian Mulberry. Somewhat smaller than the preceding, with a bushy and more compact crown.

Myrica carolinensis, Northern Bayberry. This is the native bayberry widely used for bayberry candles and similar Christmas purposes. It is a favorite for seaside planting but can be more widely used to advantage.

Myrica cerifera, Southern Waxmyrtle. This species has been used experimentally in hedge plantings, and while the experiment has not been entirely successful, it would appear that in a situation better adapted to the species the results would probably be satisfactory.

Ostrya virginiana, American Hophornbeam. A small hardy native tree of considerable interest but not recommended for general landscape planting. More satisfactory in the margins of woods or in ravines, under partial shade.

Oxydendrum arboreum, Sourwood. This fine southern species is not quite hardy in Amherst.

Pachysandra terminalis, Japanese Pachysandra. A dwarf hardy ground cover now well known. Grown for many years on the campus with utmost satisfaction. Especially adapted to shaded situations, such as under trees.

Paulownia tomentosa, Royal Paulownia. A coarse tree with large, striking foliage, much resembling catalpa, and with large trusses of beautiful showy purple flowers. Unfortunately this species is not entirely hardy here but kills back rather frequently. Occasionally it can be brought into blossom. Even when cut back from year to year the strong young shoots with large foliage have considerable ornamental value.

Phellodendron amurense, Amur Corktree. A fine, dignified tree, native of China and Japan, represented on this campus by one young specimen only. This seems to be hardy, clean, and desirable.

Phellodendron sachalinense, Sakhalin Corktree. A good-sized tree, native of Korea and northern Japan, with corky bark, striking pinnate foliage, flowers attractive but not conspicuous. Several good specimens, one of large size and striking beauty, have long shown the hardiness and adaptability of this species. It is, in fact, one of the most effective and desirable of exotic trees in the entire collection. The flowers produce an abundance of nectar, making the tree a most desirable one for the apiarist.

Philadelphus coronarius, Sweet Mockorange. This fine, old-fashioned shrub does well in this locality. Perhaps the large-flowering variety (*grandiflorus*) is to be preferred, and indeed it is the one most frequently offered by the nurseryman. In general the plant needs considerable pruning to keep it down to the ground and prevent the formation of tall, leggy stems.

Philadelphus lemoinei, Lemoine Mockorange. A very fine hybrid sort, good habit of growth with relatively small leaves and highly floriferous. Well worth general planting.

Philadelphus pubescens. Hoary Mockorange. A strong-growing, lusty, hardy species useful in mixed plantings. It has much the same ornamental values as *P. coronarius.*

Photinia villosa, Photinia. A large shrub attaining a height of fifteen feet, can be trained to tree form, with good dark green foliage. The clusters of small white flowers are quite attractive. The abundance of bright red fruits makes this a strikingly attractive plant in autumn.

Physocarpus bracteatus, Twinpod Ninebark. A rather compact, medium-sized shrub, flower clusters much resembling spirea and produced in abundance. The light green leaves strikingly like those of the garden gooseberry. It has proved to be perfectly hardy.

Physocarpus intermedius. Illinois Ninebark. Very much like the preceding but of somewhat larger growth and of equal hardiness.

Physocarpus opulifolius, Common Ninebark. A strong, coarse-growing native shrub, adaptable for large coarse masses and where a rapid filler is needed. A variety with golden-yellow leaves is not so good.

Picea canadensis, White Spruce. This native spruce is not entirely at home on the campus, preferring higher altitudes and colder, moister land. The same might be said of the Silver White Spruce (*Picea canadensis caerulea*).

Picea engelmanni, Englemann Spruce. In its native habitat this makes a fine tree and in its juvenile condition is one of the most interesting evergreens even in our locality. However, it is not well adapted to this soil and climate, and does not make a permanent tree of outstanding value. The same could be said of the Blue Englemann Spruce (var. *glauca*).

Picea excelsa. Norway Spruce. This has been extensively used on the college campus and makes a very good tree, shapely and attractive, reaching a height of about forty feet. At the end of thirty or forty years, however, these specimens begin to grow ragged, especially about the bottom, and from this time on deteriorate steadily. They are also badly attacked by gall-aphid. They make excellent hedges, also good Christmas trees, and are generally very attractive during the juvenile stages. As they are hardy and easy to grow they can be used in considerable quantities, but it is good management to weed out the older specimens.

Picea excelsa compacta. Globe Norway Spruce. One very fine specimen of this dwarf spruce is found on the college campus. It is one of the most satisfactory curiosities in its class.

Picea excelsa cupressina. Somewhat more columnar in form than the species and closer branching so as to produce a very dense crown.

P. excelsa pendula. Another odd form is represented by an old tree on the campus. Interesting only as a curiosity.

Picea pungens, Colorado Spruce. These spruces have been grown in considerable numbers and variety on the college campus. They are thrifty and hardy and fairly satisfactory during their early years. After reaching the age of twenty or thirty years, however, they begin to deteriorate.

Picea pungens glauca. Blue Colorado Spruce. This very popular curiosity has been widely planted through the country and a number of good specimens have been grown on the campus. At the age of twenty-five to thirty years they begin to lose their lower branches and soon have to be removed. This species has been greatly overvalued and overplanted throughout the country generally.

Picea rubra. Red Spruce. This native species, like the white spruce, requires colder, moister soil than is available on the college grounds. It makes rather picturesque specimens but is not to be recommended for general planting.

Pieris floribunda. Mountain Andromeda. A delightful small evergreen shrub with beautiful, white, waxy flowers in spring. Hardy and satisfactory here, and to be generally recommended for planting on home grounds and in the finer sections of parks.

Pieris japonica, Japanese Andromeda. A fine, hardy evergreen shrub something like the American species and equally attractive as a garden plant.

Pinus banksiana, Jack Pine. As far as the college plantings are concerned this is "just another pine." It has no outstanding characters to recommend it for general planting.

Pinus cembra, Swiss Stone Pine. An attractive symmetrical tree useful in ornamental planting. It has not proved to be a long-lived tree on the campus.

Pinus montana mughus, Mugho Pine. A dwarf pine widely planted and quite satisfactory. Old specimens have a tendency to get ragged and bushy. When this condition arises, the plants may be heavily cut back and allowed to branch out and start again, or they may be cut out and thrown away, their place being taken by fresh young stock. This plant is so much better during its early years than during its later years that it seems hardly worth while to keep it after it begins to get ragged.

Pinus nigra, Austrian Pine. One of the best pines for general ornamental planting, rugged, symmetrical, with good foliage. The tree is not very large, but seems to be permanent and satisfactory.

Pinus resinosa, Red Pine. A fine, strong-growing, lusty species of prime value in forest plantations and excellent for heavy masses in landscape work. One of the best of all the pines.

Pinus rigida, Pitch Pine. Grows abundantly throughout the region, but especially upon dry gravelly sterile soil. It is picturesque in form. It is easy to propagate and transplant and is really worthy of frequent consideration where plantations have to be established on sand or gravel. It is especially abundant and attractive in the Cape Cod region.

Pinus strobus, White Pine. This native species is a deserved favorite. It is attractive in all conditions whether young or old. It does well on a variety of soils from moderately dry to moderately moist. It makes excellent specimens or fine woodland plantings, and has an outstanding forest value. When thickly set and closely sheared it makes a fine hedge. One serious drawback is found in its susceptibility to the attacks of the pine borer. This insect cuts out nearly all the leaders when they reach a height of about ten feet. The more recently introduced white pine blister-rust is also a menace to this species.

Pinus sylvestris, Scotch Pine. A thrifty, hardy pine which makes itself entirely at home on the college grounds and reproduces itself freely from seed. It is a picturesque, attractive tree for mass planting, but does not make good symmetrical specimens. The ease with which it reproduces and transplants recommends it for general use.

Platanus occidentalis, American Planetree. This native species is thoroughly hardy and satisfactory, being especially at home along the moist banks of streams and in alluvial land. It is a rapid-growing tree, large and lordly though not especially symmetrical. Its foliage and bark present an interesting coarse texture. This species is distinctly useful in certain kinds of park planting, especially for large masses viewed from some little distance.

Platanus orientalis, European Planetree. This species generally forms a more symmetrical and attractive specimen than its American congener, but does not seem to be fully adapted to this climate. Apparently it does much better farther south.

Populus alba, White Poplar. Like all the poplars this makes a rather poor tree, but where quick results are required it may be used for temporary planting.

Populus bolleana, Bolleana Poplar. Botanically this is but a columnar

form of the white poplar. Though extensively proclaimed as a substitute for the decadent Lombardy poplar the campus trees show no improvement over that variety.

Populus nigra italica, Lombardy Poplar. A few trees of a very early planting on the campus still survive, but, as is so very common with the variety, they are very ragged and unsightly. Because of its poor vitality this once very popular tree seems doomed. Its rapid growth might recommend it for immediate and temporary effect but it is not to be considered in a permanent planting.

Prunus americana, American Plum. Various types of this species (also of other native American species) have been planted on the grounds, usually as pomological experiments. Nearly all of these native plums, however, have considerable decorative value; most of them are distinctly hardy and well adapted to ornamental planting. Of these the most available seem to be *P. americana* and *P. hortulana*.

Prunus avium, Mazzard. This old European species of cherry with its various ornamental varieties has been frequently planted on the college grounds. It is not entirely adapted to this locality but can be grown.

Prunus besseyi, Bessey Cherry. This species has been used rather extensively on the grounds in an experimental way, mainly as a stock for other species of prunus, including the common orchard plum. For this purpose it has considerable value. As a decorative plant it may be dismissed altogether. The flowers of this species and all its hybrids are extremely susceptible to brown rot fungus. For this reason a mature fruit is a great rarity. The closely related species, *Prunus pumila*, native to Massachusetts, has also been tried with about the same negative results. While it may have some value for wild plantations along the seashore it is hardly to be recommended for use in the Connecticut Valley.

Prunus cerasus rhexi, Rhex Cherry. One tree, now about fifty years old, each year produces a mass of double white flowers. This is a very attractive specimen and is fully hardy.

Prunus demissa melanocarpa, Black Western Chokecherry. Rather similar to the native chokecherry of the Eastern States differing chiefly in ranker growth.

Prunus glandulosa glabra albiplena, Double Pinkflowering Almond. This is the low-growing rather compact shrub with pink double flowers, commonly known simply as "flowering almond." Because of its dwarfish habit of growth it has been listed in some nursery catalogues, erroneously, as *Prunus nana*. It is entirely distinct from that species, no variety of which is reported as having double flowers. The double pinkflowering almond has been planted on the campus several times, but always perished within a few years.

Prunus pennsylvanica, Pin Cherry. A hardy, native, small tree, rather weedy, and of quite temporary character. Nevertheless it is interesting; it has abundant flowers in season; and the fruits are very acceptable to the birds. It might be freely used in large woodland border plantings.

Prunus serotina, Black Cherry. A native tree seldom making large size in this latitude. Heavily attacked each spring by tent caterpillars. Rather weedy and unattractive, and not to be recommended for landscape planting except for extremely wild conditions.

Prunus serrulata sachalinensis, Yama Cherry. One of the fine, large, ornamental Japanese cherries. Perfectly hardy and satisfactory.

Prunus subhirtella ascendens, Shiro-higan Cherry. One of the very best ornamental Japanese cherries; hardy, permanent, and satisfactory. There is a weeping variety of the same species, but this upright variety is much more desirable.

Prunus triloba plena, Doubleflowering Plum. This highly ornamental variety has been used on the grounds as a small formal tree budded on hardy stock. The flowers are large, double, and very showy. This seems to be fairly hardy and reasonably permanent, and worthy of recommendation as a hardy flowering shrub. This is one of the plants that are often though erroneously called "flowering almond."

Pseudotsuga douglasi, Douglas-Fir. A strong-growing evergreen suited to mass plantings, borders, and screens.

Ptelea trifoliata, Common Hoptree. A curious and interesting native shrub or small tree. Rather sprawling and awkward and suited only to planting along woodland borders.

Quercus alba, White Oak. A hardy native tree of considerable value. Unfortunately it is rather hard to transplant and slow-growing while young. When once established it grows more rapidly than is commonly supposed, and should be more frequently used.

Quercus bicolor, Swamp White Oak. A fine, strong, thrifty species well worth more general use; makes excellent specimens. The campus has one notable specimen about fifty years of age and the species is used freely in general mass plantations.

Quercus coccinea, Scarlet Oak. An attractive native species comparatively easily transplanted and well worth general use.

Quercus imbricaria, Shingle Oak. A fine, attractive species, probably one of the best of the oaks for general park planting.

Quercus macrocarpa, Mossycup Oak. An interesting species but of no particular horticultural value in this latitude.

Quercus palustris, Pin Oak. A native tree adapted to moist soil along streams, but will do well on a more elevated location if not too dry. It makes a very symmetrical tree, of good foliage texture. The characteristic spread of its branches gives it a very attractive appearance in winter. It is becoming justly popular as a street tree.

Quercus robur, English Oak. Much resembling native white oak though of smaller and more compact growth. It is perfectly hardy.

Quercus rubra, Common Red Oak. One of our native oaks that is well worthy of consideration in large plantings. Isolated specimens develop wide-spreading, rounded crowns.

Quercus velutina, Black Oak. This is another of our common native oaks, often associated with the last. It is more upright in habit and suitable for groups in larger plantings.

Rhamnus cathartica, Common Buckthorn. A hardy and satisfactory shrub for general mass planting. Formerly this species was frequently used for sheared hedges, being especially popular in eastern Massachusetts. It has been tried for hedges on the campus without much success.

Rhamnus frangula, Glossy Buckthorn. More slender and graceful than the common buckthorn and a rather better shrub for general planting. In fact this species seems to be worthy of more attention than is commonly given to it by nurserymen and landscape architects. Very attractive in the autumn because of the abundance of shiny purple-black fruits.

Rhododendron catawbiense, Catawba Rhododendron. This handsome evergreen shrub has been growing on the campus for many years and proves to be perfectly hardy. It is represented by a number of flower-color varieties—probably hybrids. It requires an acid soil and is a superb plant for such locations.

Rhododendron maximum, Rosebay Rhododendron. A native large evergreen shrub. Though flowers and flower clusters are not so large and showy as those of *R. catawbiense*, yet it is a handsome plant and worthy a place in any collection. It, too, requires an acid soil.

Rhododendron micranthum, Manchurian Rhododendron. Plants of this species have been growing on the campus for several years, but indifferently. They do not appear to be adapted to conditions here.

Rhus canadensis (*aromatica*), Fragrant Sumac. Native shrub less known than some others but very desirable for general planting in parks, public grounds and even in small private gardens; growth somewhat prostrate, four to six feet, good foliage and bright autumn colors; requires no care; has more advantages and fewer disadvantages for garden use than any other member of the genus.

Rhus copallina, Shining Sumac. Dwarf native shrub, resembling the smooth sumac, but dwarfer with smaller leaves; autumn colors good, especially when combined with other sumacs, the shining sumac always being the darkest. Very hard to transplant, but otherwise good for landscape effects.

Rhus cotinus, Common Smoketree. A large shrub or bushy tree with showy sterile blossoms, used occasionally as an ornamental specimen plant; not especially valuable.

Rhus cotinus atropurpurea, Purple Smoketree. A variety of the foregoing with purplish fluffy sterile panicles in late summer and autumn, of no special value except as a curiosity.

Rhus glabra, Smooth Sumac. A very common native shrub frequently used in park planting for broad and coarse effects. Especially desirable for its fall colors. Easily transplanted; suckers badly.

Rhus glabra laciniata, Cutleaf Sumac. A variety of the foregoing, with finely dissected foliage; only a curiosity in the same class as the shredded sumac.

Rhus javanica (*osbecki*), Java Sumac. A fair-sized tree; one specimen on the college grounds grew for several years reaching a height of fifteen feet; flowers showy, appearing late in the season; more effective as a specimen than other sumacs and apparently less inclined to sucker.

Rhus toxicodendron, Poison Ivy. A native shrubby vine everywhere abundant and everywhere beautiful in spite of its bad social habits. The only effective method of eradication is by uprooting. This is an endless job since birds scatter the seeds over wide areas and seedling plants are abundant everywhere.

Rhus typhina, Staghorn Sumac. A large, coarse, very common native species used in park work and broad naturalistic plantings; good autumn colors. Fairly easy to transplant; suckers considerably.

Rhus typhina laciniata, Shredded Sumac. A variety of the above with very much dissected foliage; interesting as a curiosity but of little value otherwise.

Rhus verniciflua, Lacquer-tree. A small tree from Japan and China, showy in foliage. This species was grown for several years on the campus but had to be suppressed because it proved unusually poisonous—much more aggressive in this respect than the well-known poison ivy. Otherwise it is desirable.

Rhus vernix, Poison Sumac. Native shrub growing in swamps, beautiful but very poisonous, colors finely in autumn, white or light buff berries.

Ribes odoratum, Golden Currant. An attractive little shrub with fragrant yellow flowers, now generally interdicted as an intermediate host in the white pine blister-rust.

Robinia pseudoacacia, Common Locust. This rather weedy tree has some value for general park planting, more especially on waste land. It is perfectly hardy here but does not show with such comparative favor as in some of the sandier seacoast towns. Suckers badly.

Robinia viscosa, Clammy Locust. A large shrub with attractive pink flowers. Has minor value for mass planting. Very susceptible to injury by locust-twig borer. Like the common locust it suckers very freely.

Rosa blanda, Meadow Rose. An attractive native rose suitable for wild garden use, preferably in moist, somewhat sunny meadow locations. Spreads freely by root suckers.

Rose hybrid, F. J. Grootendorst. This rose has been tried as a hedge plant. Apparently it can be used for this purpose exactly as *Rosa rugosa*, one of its parents, is frequently used; that is, to make a hedge border to be left unsheared. It is more floriferous and has a much longer flowering season than *R. rugosa* and is to be preferred on this account.

Rosa multiflora, Japanese Rose. A strong, lusty-growing plant, rather coarse. Flowers abundant, in large clusters, usually with a rather unpleasant odor. This is, however, a strikingly satisfactory shrub for many sorts of plantings, both because the plant is strong and hardy and because it is distinctly floriferous. The bright hips lasting far into the winter are also ornamental and may possibly be attractive to birds.

Rosa palustris, Swamp Rose. A native species, usually of low growth, best adapted to wet soil in large plantations.

Rosa rugosa, Rugosa Rose. This hardy and popular Japanese rose has been extensively used on the college campus. It has substantial value in general plantings but appears to special advantage on exposed seashore locations. The white-flowering variety is quite attractive; and several of the hybrids are distinctly promising.

Rosa setigera, Prairie Rose. One of the best of all the "wild" roses. Very hardy and floriferous, blooming latest of all. Excellent for general planting.

Rubus deliciosus, Boulder Raspberry. Plants introduced about six years ago from Colorado prove to be fully hardy, and promising for ornamental planting. A rather compact rounded shrub with good foliage and flowers.

Rubus odoratus, Flowering Raspberry. A coarse native shrub with broad hairy leaves and dull purplish-red blossoms, followed by even duller purplish-red fruit. Suitable for mass plantings in rough, back-stage plantations.

Salix babylonica, Babylon Weeping Willow. This tree, formerly very popular, is now fortunately going out of style. It may be used occasionally but has no special dignity and is untidy on the lawn.

Salix bebbiana, Beak Willow. A native species of no particular merit.

Salix blanda, Wisconsin Weeping Willow. Of all the weeping willows this seems to us best. Several specimens on the campus, having reached the age of approximately fifty years, show considerable dignity.

Salix caprea, Goat Willow. This species is sometimes grown in nurseries for its catkins, the branches being cut and forced for "pussywillows." It has no other special merit.

Salix cordata, Heartleaf Willow. A native shrubby species making rather dense thickets in wet meadows and along streams. May be used in such locations in large plantings.

Salix discolor, Pussy Willow. The branches of this species are also cut and forced for "pussywillows." If protected from human depredations will make a very acceptable large shrub when planted in moist situations. Best adapted to large natural plantings.

Salix fragilis, Brittle Willow. One of the better ornamental sorts, especially good if cut back annually allowing the bright yellow shoots to appear to advantage in the spring coppice.

Salix purpurea, Purple Osier. The soft young shoots of this species have sometimes been used for basket making It has little or no value as an ornomental.

Salix vitellina aurea, Russian Golden Willow. When allowed to grow, this makes a sizable tree, about as good as any willow. Like many of the willows it gives its best ornamental effect if cut back annually or at least every other year and allowed to grow as coppice. In this way the bright golden-yellow twigs are conspicuous and attractive, especially in early spring. It seems well suited also, for an informal hedge.

Sambucus canadensis, American Elder. A hardy native species, somewhat coarse in foliage but very attractive in blossom. Suited for wild mass plantings, especially along water courses and by small ponds.

Sambucus nigra laciniata, Cutleaf European Elder. A rather showy and interesting abnormality which should appeal to every collector of freaks.

Sambucus pubens, Scarlet Elder. A fine, hardy native species suited for general planting. The blossoms are rather attractive and the red fruits more so. Adapted to a drier situation than the more common American elder.

Sassafras variifolium, Common Sassafras. This species is nearly at its northern geographical limit in Amherst. From time to time it suffers from severe winter weather. A few fine large trees forty feet in height were killed by the severe winter of 1917-18. This is especially attractive for its beautiful autumn colors. It makes a splendid showing in woodland borders. Such plantations represent its highest decorative use.

Sciadopitys verticillata, Umbrella-pine. This beautiful oriental conifer was early introduced to the campus and the college still has two exceptionally fine specimens. It is a most attractive novelty and well worth using, either as a specimen or in general coniferous plantations.

Shepherdia argentea, Silver Buffaloberry. A rather interesting, hardy, large-growing shrub with silvery foliage, offering a striking contrast in mixed plantings. Quite useful in its way.

Sorbaria arborea, Tree-spirea. A large lusty-growing shrub with strong pinnate leaves and large trusses of gorgeous white flowers. This seems to be perfectly hardy and worthy of recommendation.

Sorbus americana, American Mountain-ash. This species is somewhat less formal and symmetrical than the European mountain-ash and better adapted to planting in woodland borders and garden borders generally.

Sorbus aucuparia, European Mountain-ash. A well-known small tree, interesting and useful for planting as single specimens on small grounds. Attractive for its fruit.

Spiraea arguta, Garland Spirea. One of the best of the small spireas, of good habits and good foliage and fairly attractive flowers. Suitable for general massing and grouping on lawns. One of the first to blossom in the spring.

Spiraea billiardi, Billiard Spirea. This species has been widely sold and used but seems to be less attractive than several of the other spireas.

Spiraea bumalda, Bumalda Spirea. Another well-known species for which one might better substitute something else.

Spiraea henryi, Henry Spirea. A rather tall upright shrub of good foliage and an abundance of flowers. Good as a background plant in shrubberies or foundation plantings.

Spiraea latifolia, Pink Meadow Spirea. A hardy native species suited to rather moist land.

Spiraea media, Oriental Spirea. Much like the Henry spirea in all respects, except not so tall, and may be used in like situations.

Spiraea prunifolia plena, Double Bridalwreath. An old favorite and most attractive when in good health. It is not entirely hardy, however, and cannot be recommended for general planting in this latitude.

Spiraea tomentosa, Hardhack. A coarse, tough, hardy native species suitable for planting in wild gardens.

Spiraea thunbergi, Thunberg Spirea. One of the most popular, small to medium in height, of pleasing habit and attractive foliage, which takes on a fine rich color in autumn. The flowers are somewhat sparse but pretty. The whole plant is well worth using in spite of the fact that it is not entirely hardy. The shoots kill back at the tips nearly every winter, but by removing

the killed portions it is possible to have fairly good plants at all times. From the purely decorative point of view this is one of the best of all the spireas.

Spiraea vanhouttei. VANHOUTTE SPIREA. One of the most popular and widely used shrubs in the whole nursery catalog, and indeed one of the best. Perfectly hardy and satisfactory.

Staphylea trifolia, AMERICAN BLADDERNUT. A rather interesting small tree or large shrub. Suitable for planting in woodland borders.

Stephanandra flexuosa, CUTLEAF STEPHANANDRA. A delicate and attractive shrub of good form and texture. Very suitable for mass planting on the lawn and in general park work. Its one defect is a tendency to kill back at the tips of the branches during the winter. Nearly always the plants need going over in early spring, cutting out these small dead portions. This defect, however, is not very serious, and the plant is well worth the extra trouble required.

Symphoricarpos racemosus, COMMON SNOWBERRY. An attractive small shrub with graceful habit of growth. Its most pleasing feature consists of a fine crop of waxy white berries which persist far into the winter. Excellent for foundation plantings and general use on small lawns.

Symphoricarpos vulgaris, CORALBERRY. A hardy, solid, rather satisfactory shrub of moderate height and medium texture. The bright red berries which persist well into the winter are a feature.

Syringa, LILAC. A considerable number of the hybrid lilacs have been tested here and found generally very satisfactory, much to be recommended in preference to the wild, weedy, unselected varieties from the roadside.

Syringa japonica, JAPANESE TREE LILAC. This Japanese species has long been growing on the college campus, the older trees attaining a height of twenty-five feet. The flowers are borne late in the season in very large showy clusters, the odor being unfortunately unpleasant. Still this is an ornamental tree worth using in many collections.

Syringa pekinensis, PEKING LILAC. A good, hardy species, worth a place in the shrubbery collection. Later in its blossoming period than the more common species.

Syringa persica, PERSIAN LILAC. A fine, strong plant with fragrant flowers smaller than the common lilacs. Well known and always to be recommended.

Syringa villosa, LATE LILAC. A strong, hardy shrub of rather upright growth. Flowers freely considerably later than the ordinary lilac. Unfortunately the blossoms are not fragrant, or at least not agreeably so. Otherwise this shrub is well worth general use.

Syringa vulgaris, COMMON LILAC. Various forms of the common lilac have always been growing on the college grounds. These are hardy and thoroughly satisfactory, not even being troubled by the mildew, or at least not frequently. They are excellent for mass planting in borders, etc., but for fine ornamental effects they should be replaced with the better hybrid varieties.

Tamarix odessana, ODESSA TAMARIX. A shrub with tall, slim willowy branches and feathery green foliage. Rather different and interesting. Not entirely hardy.

Taxus baccata, English Yew. This species is not hardy here, and the golden-foliaged variety is only partly so.

Taxus canadensis, Canada Yew. A hardy, dwarf, almost prostrate, native evergreen suitable for underplanting in cold situations.

Taxus cuspidata nana, Dwarf Japanese Yew. A small evergreen satisfactory for foundation planting and general ornamental work. This seems to be entirely hardy here.

Thuja occidentalis, American Arborvitae. This hardy native species has been frequently used on the college campus for single trees, for windbreaks, for screen plantings, and for hedges. It is very adaptable for all such purposes, and can be highly recommended. Its chief weakness seems to be that it suffers from severe drought, especially when a dry autumn is followed by cold windy weather in winter.

Tilia americana, American Linden. The common American linden or basswood can be grown here, but does not do particularly well. It is worth keeping in a collection, but as an ornamental tree is far inferior to the European species.

Tilia platyphyllos, Bigleaf European Linden. As grown on the campus this is the best of all lindens, a shapely, fine tree with good foliage and generally bearing a fine crop of honey-producing flowers.

Tilia vulgaris, Common Linden. Not quite so good a tree as the preceding and more inclined to an early fall of foliage through insect injury.

Tsuga canadensis, Canada Hemlock. The native American hemlock is one of the best of all evergreen trees for general ornamental planting, for use as windbreaks, for shearing into hedges, and even for specimen trees on the lawn. It should, however, be given a cool soil and situation, preferably a northern slope. There is a weeping variety (var. *pendula*) interesting as such novelties go.

Tsuga caroliniana, Carolina Hemlock. This species has been rather fully tested on the campus in general plantings, as specimens, and in hedge rows. It shears well and makes a good hedge, and is a first-class addition to the list of hemlocks, though in general it would not be preferred to the more common Canada hemlock.

Ulmus americana, American Elm. The most popular street tree and one of the best for general park and lawn planting. Quite variable. According to observations here, the nursery-grown trees are much to be preferred to those collected from the wilds.

Ulmus campestris aurea, Golden English Elm. One fine specimen of this tree, now nearly fifty years old, is a feature of the college campus. It needs a little attention in the way of pruning to cut out reverting branches with green foliage. For a novelty of this sort the golden elm is unusually satisfactory.

Ulmus glabra, Scotch Elm. Less symmetrical than the American elm, top rounder and more spreading. Interesting by way of variety but far less valuable than the American species.

Ulmus glabra camperdowni, Camperdown Elm. Several specimens of this monstrosity have been planted on the college campus; two or three of these have done as well as could be expected.

Ulmus japonica, Japanese Elm. This was one of the first specimens brought over by the Japanese friends of Massachusetts Agricultural College. Three very good specimens are on the campus, one a fine large tree forty to fifty feet high, very shapely and symmetrical. From experience here it would seem that this species is well worth further notice.

Viburnum acerifolium, Mapleleaf Viburnum. A fine, hardy native species valuable for underplanting in woods and generally in shade. Takes an attractive autumn color.

Viburnum carlesi, Fragrant Viburnum. Of comparatively recent introduction, this shrub has been carefully tried on the college grounds and proves to be hardy and satisfactory. The flowers have the fragrance and somewhat the appearance of the much sought trailing arbutus, and the shrub will always be prized for this reason. It is a fairly good, medium-sized shrub, hardy and satisfactory for lawn use.

Viburnum cassinoides, Withe-rod. A fine, hardy native species, good strong-growing shrub, ten to twelve feet high with heavy foliage and good flowers; makes excellent masses for heavy mass plantings, especially along borders.

Viburnum dentatum, Arrowwood. One of the best of all the viburnums for general landscape planting. Especially good for borders. The foliage is clean and bright and the white flowers attractive. Prefers a moist soil.

Viburnum dilatatum, Linden Viburnum. A fine, strong, hardy shrub rather upright in growth, with good foliage and an abundance of beautiful red berries which hold well into the winter. This is a recent introduction on the campus, but has shown itself to be highly desirable.

Viburnum lantana, Wayfaring-tree. A coarse, sprawling shrub with large leathery, gray-green foliage. Excellent for certain kinds of planting, especially under trees, but not good for grouping on the open lawn nor for specimen use.

Viburnum lentago, Nannyberry. A tall, upright-growing, strong native shrub good for heavy plantings in rather wild surroundings. Not quite so attractive in habit and flower as some of the other viburnums.

Viburnum opulus, European Cranberrybush. This species was formerly very popular and widely planted on private grounds. It is much subject to the attacks of aphis, however, and does not seem to be so good as other viburnums for general planting.

Viburnum sargenti, Sargent Cranberrybush. This is the Asiatic representative of the group which includes *V. opulus* of Europe and *V. americana* of the Western Hemisphere. In habit of growth, foliage, and flower, it is strikingly like *V. opulus* and should receive like consideration.

Viburnum sieboldi, Siebold Viburnum. A large sturdy shrub with attractive light green foliage and abundantly floriferous. Reputed to be especially attractive when in fruit. The one plant on the campus has never fruited. It proves perfectly hardy and worthy of consideration in plantings.

Viburnum tomentosum, Doublefile Viburnum. A strong, lusty, large-growing, spreading or round-topped shrub with coarse, strong foliage, and bearing broad, flattened clusters of showy white blossoms. One of the hardiest and most striking of the viburnums and highly useful for general land-

scape planting. As this is a Japanese species, however, it might be better to use native American sorts for strictly natural effects.

Viburnum tomentosum plicatum, JAPANESE SNOWBALL. The variety of the foregoing which has flowers in a large round cluster like a popcorn ball. Formerly this was rather popular, but in general it is not so good as the doublefile viburnum.

Viburnum venosum. VEINY VIBURNUM. Very like *dentatum* in habit of growth and character of foliage and flowers though somewhat coarser. Its special attraction is the abundance and bright blue color of its fruits in autumn. It is fully hardy.

Vinca minor, COMMON PERIWINKLE. A low-growing or prostrate hardy vine, very tolerant of adverse conditions; will grow in shade or sun and on dry or arid land. It is especially useful for ground cover in difficult situations.

Vitis labrusca, FOX GRAPE. The native fox grape is hardy and may sometimes be used for purposes similar to the following species, though in general its ornamental value is considerably less than that of the riverbank grape. Other native species of grapes are satisfactory for landscape use in much the same way as suggested below for the riverbank grape.

Vitis vulpina, RIVERBANK GRAPE. A fine hardy, native vine, excellent for general planting on pergolas, fences, or arbors, and very satisfactory for growing over stone walls, cut banks, and similar positions.

Weigela rosea, PINK WEIGELA. A medium-sized, round-topped, neat hardy shrub with good, showy flowers. They are generally quite popular for ornamental use on small lawns and similar home surroundings. They make fairly good foundation plantings. Most of the plants on the campus are of the composite group commonly listed as *W. hybrida*—of uncertain parentage and great variation in foliage and flower characters.

Wisteria floribunda, JAPANESE WISTERIA. A strong hardy vine and popular. Suitable for all sorts of locations where a heavy climber is desirable. In this locality the species is particularly difficult to flower. While this disinclination toward flower-bearing seems to characterize the species widely, there is apparently a tendency for it to be much more floriferous along the seashore. Many suggestions have been made about bringing this vine into better flowering habits, by pruning or change in feeding; but while some of these methods have been tried here none has given satisfaction.

Zanthorhiza apiifolia, YELLOWROOT. A dwarf shrubby plant, very hardy and permanent, suitable for underplanting, for the margins of shrubberies, and especially for holding banks against washing. Flowers inconspicuous, but foliage clean and particularly good.

Zanthoxylum americanum, COMMON PRICKLEY-ASH. A hardy native species of some value for garden and park planting, though seldom included in nursery catalogs.

Publication of this Document approved by the Commission on Administration and Finance.

6m-11-'30. No. 524

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 268 December, 1930

Frozen Sweet Cream as an Ingredient of Ice Cream

By M. J. Mack

The economical use of the large surplus of milk produced during the early summer months is one of the major problems which annually confronts the dairy industry. In recent years an appreciable part of this surplus has been stored as frozen sweet cream. This study was undertaken to determine the most satisfactory method of utilizing the product in the manufacture of ice cream.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

FROZEN SWEET CREAM AS AN INGREDIENT OF ICE CREAM

By M. J. Mack[1]

Assistant Professor of Dairy Industry

INTRODUCTION

The seasonal variation in milk production has always been a serious problem confronting the dairy industry. In New England there is invariably a large surplus of milk and cream in May and June, while September, October, and November are usually the months of lowest production. Any satisfactory method of storing milk products during periods of surplus, for use during months when the demand is greater than the supply, is of economic importance to the producer, the consumer, and the manufacturer of dairy products.

Condensed and evaporated milk, milk powder, and butter are common storage products rich in milk solids. The problems of manufacturing and handling these products have been fairly definitely worked out. The storage of cream in the frozen state has also become a relatively common practice in recent years. The fact that very little investigation has been reported regarding the handling and use of frozen cream indicated a need for the study of this product as an ice cream ingredient.

PREVIOUS INVESTIGATIONS

Some experimental work has been reported regarding the keeping quality of frozen cream. Dahle (1) states: "The quality of the initial cream before freezing and the storage temperature are the important factors contributing to the quality of ice cream made from frozen cream. When a surplus of cream of uncertain quality is to be disposed of, it is better to make it into unsalted butter for storage than to store it as frozen cream. Fresh sweet cream, frozen and stored at 5° F. for four months, afforded as good a source of fat for ice cream as unsalted butter made from the same source of cream and stored under identical conditions."

Ellenberger and White (2) show that frozen sweet cream of good quality, pasteurized at 145° F. for 30 minutes and held at—10° to 10° F., was "almost as good after 6 months as when fresh," when stored in good quality granite ware or in lacquered 5-pound butter storage cans. That stored in well-tinned cans kept well but lacked "the pleasing fresh cream flavor." Cream not pasteurized was of inferior keeping quality. Cream stored in cans having rusty iron spots (1.0 per cent of the container surface) was reported as being metallic in two months. Cream exposed to copper before freezing became unfit for use in two months (metallic). High pasteurization temperatures of 180° F. for 30 minutes were reported as being unsatisfactory. These workers also state that acidity development of 0.15 per cent caused frozen cream to become unfit for use in two months.

[1] Acknowledgment is due Stephen Adams and Huntington Rutan for their help in securing a part of the freezing data.

Newlander and Ellenberger (3), in the same annual report, state that frozen cream from fresh cream of initial high quality, testing 40 per cent fat, after 9 months of storage at 0° F., made a 20 per cent cream of good flavor equal to the cream made from butter oil stored under the same conditions.

Tracy (4) found it possible to store frozen cream at low temperatures for three and one-half months without "greatly affecting the flavor of the butterfat." He found that high-testing creams kept better than low-testing creams. Pasteurized cream was found to keep better than raw cream, and that with reduced acidity showed less deterioration than cream with normal acidity. Paraffined paper containers were found to be satisfactory if air was excluded. Cream exposed to the air soon acquired a bitter flavor. Rusty cans were reported as causing a metallic flavor. Temperatures below 0° F. were found to be more satisfactory than higher temperatures.

In the same investigation, Tracy also reports that concentrated ice cream mixes were stored in the same manner as the frozen cream. In comparing ice cream mixes made from frozen cream, frozen condensed mix, and unsalted butter, all from the same lot of cream and stored for four and one-half months, that from frozen cream ranked first in quality.

In the previous investigations with frozen cream, factors affecting the keeping quality of the product were studied and their effects established. However, no attention was given to the effect of this ingredient on the physical properties of the ice cream mix. In this investigation, the first consideration has been to compare fresh and frozen cream mixes as to their relative viscosity, rate of freezing, microscopic appearance, etc. Different methods of treating the cream previous to freezing have been studied. Some data have also been collected on the keeping quality of frozen cream.

EXPERIMENTAL PROCEDURE

The mixes were tested for fat and total solids by the Mojonnier method. The composition varied within narrow limits and averaged 14 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.4 per cent gelatin. The milk products used were either fresh or frozen cream, skim milk, and skim milk powder. The ingredients were pasteurized at 145° F. for 30 minutes. The mixes were homogenized at the pasteurization temperature at a pressure of 2,500 pounds per square inch, immediately cooled to 45° F., and then held for 24 hours at 40° F. before freezing.

The initial cream used for frozen cream was of the same quality as that used in the sweet cream mixes. No off flavors or odors were apparent. The acidity range, expressed in terms of lactic acid upon titrating with a tenth normal solution of sodium hydroxide, varied from 0.10 per cent to 0.13 per cent. When cream was homogenized or sugar or gelatin added before freezing, a quantity of cream was divided into two equal parts. Both were treated identically except for the factor being studied. All batches of cream tested 40 per cent fat or more and all were pasteurized previous to freezing.

Viscosity readings were made with 100 c.c. samples of the mix after

24 hours, using the MacMichael viscosimeter. Readings were made with a No. 30 wire and the disc bob. The cup was rotated at the rate of 19.1 r.p.m. Readings were taken when the mix temperature in the cup reached 68° F. All readings are stated in degrees M.

The fat globules and clumps were measured using an ocular micrometer disc standardized with the microscope so adjusted that each of the smallest divisions represented 1.35 microns. One c.c. of the mix was diluted with 99 c.c. of distilled water and mounted as a hanging drop preparation.

All mixes were frozen in a 40-quart standard motor-driven brine freezer. The freezer was always pre-cooled by freezing a preliminary batch before any data were recorded. The percentage of overrun and temperature of the ice cream were secured at minute intervals during the freezing process. The brine was shut off at such a time that all batches were frozen to approximately 24° F. A brine held at 0° F. was employed.

All data represent an average of at least five different trials on different mixes. Where differences were not marked, a larger number of trials were made. In only one case, which will be mentioned later, did contradictory results occur.

EXPERIMENTAL RESULTS

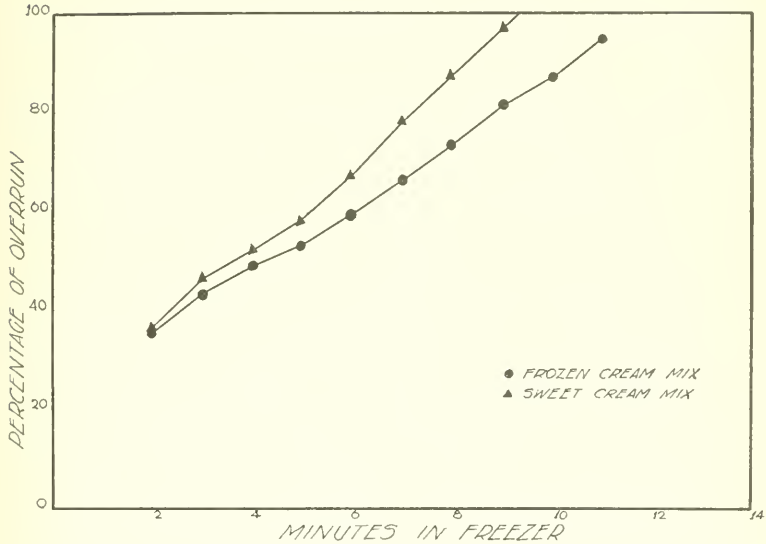
This problem was attacked by first comparing mixes made with sweet cream as the entire source of fat with those differing only in that frozen cream was substituted for sweet. Then the effects of the rate of melting the frozen cream and of the length of time in storage were established. Following this, an attempt was made to find a way of freezing cream so that its properties in ice cream mix would be more like those of fresh cream. In this part of the work, cream was either homogenized previous to freezing, frozen with 10 per cent sugar, or frozen with 0.5 per cent gelatin. Plain pasteurized frozen cream was used for the control batches.

The data in Table 1 are a summary of all the viscosity determinations and microscopic measurements of the fat phases. Figures 1, 3, 4, and 5 were compiled from freezing data collected from the same mixes as represented in Table 1. Therefore, correlations may be made between the table and figures. It should be realized that all observations were made on ice cream mixes of the same composition. Where gelatin or sugar was added to cream before freezing, this was taken into account and proper adjustments were made in the amounts of these ingredients when the mixes were prepared.

The Physical Properties of Frozen Cream Mixes

Table 1 and Figure 1 show the marked differences between mixes made from sweet and frozen cream. The frozen cream mixes averaged more than twice as viscous, according to the method used for comparison. Both the individual fat globules and the clumps were smaller in mixes made from sweet cream. A marked difference in freezing time was found. The sweet cream mixes could be drawn at 95 per cent overrun, and at a drawing temperatures of 24° F., in approximately two and one-fourth minutes less time than frozen cream mixes.

Figure 1. The Influence of Sweet Cream and Frozen Cream on the Whipping Properities of Ice Cream Mixes.



The fat globules and clumps were fairly uniform in size in sweet cream mixes. The greater number fell very close to the averages given in Table 1. This was not true of frozen cream mixes. Here wider variations were found, with some globules and clumps considerably larger than the average. This may have been caused by the fact that in frozen

TABLE 1.—THE EFFECT OF FROZEN CREAM, TREATED IN DIFFERENT WAYS, ON VISCOSITY, SIZE OF FAT GLOBULES, AND SIZE OF FAT GLOBULE CLUMPS WHEN USED IN ICE CREAM MIXES

(Average of five or more trials)*

Mix No.	Description of Cream Used in Mix	Viscosity of Mix °M.	Globules Measured *Number*	Average Size of Globules *Microns*	Clumps Measured *Number*	Average Size of Clumps *Microns*
A 1	Pasteurized sweet cream	64	125	1.10	81	4.55 x 4.05
2	Frozen cream	136	89	1.35	75	5.60 x 5.20
B 1	Frozen sweetened cream (10% sugar)	183	161	1.21	134	6.12 x 5.21
2	Frozen cream	204	197	1.35	156	7.01 x 5.80
C 1	Frozen homogenized cream (1000 lbs. pressure)	150	219	1.35	95	6.55 x 5.11
2	Frozen cream	135	125	1.37	80	6.75 x 5.01
D 1	Frozen gelatinated cream (0.5% gelatin)	182	148	1.24	138	6.74 x 5.87
2	Frozen cream	171	187	1.39	143	6.96 x 5.84

* In interpreting this table, comparisons should be made between mixes 1 and 2 under each group.

cream, after melting, the fat was no longer present in its original physical form. After frozen cream was melted, the greater number of fat globules were present in aggregates of such size that they could easily be observed. For this reason, less efficient dispersion during homogenization resulted.

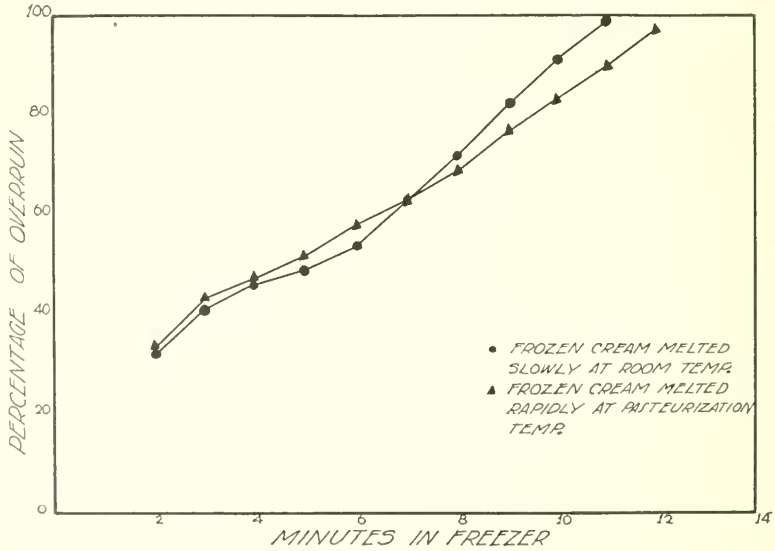
That the whipping ability of mixes is partially lost when frozen cream is used as the source of fat was found to be true. In a typical trial with a sweet cream mix, the maximum overrun obtainable was found to be 130 per cent and was secured in 13 minutes. After 3 minutes at this overrun, the percentage began to decrease. In the case of a frozen cream mix of the same composition, a maximum overrun of only 118 per cent was secured after 19 minutes in the freezer.

Rate of Melting Affects Freezing Time

The rate of melting frozen cream has an effect on the whipping properties of an ice cream mix made from it. With the exception of this part of the study, frozen cream to be used was allowed to melt slowly at room temperatures. The practice of wetting the outside of the cans, so as to prevent a layer of frost from forming, was found to help somewhat. In this part of the experiment, frozen cream mixes made from cream melted in the above manner were compared with others containing frozen cream melted rapidly. In the latter, frozen cream was placed directly in the pasteurization vat and heat was applied.

Figure 2 shows that melting the cream slowly was more satisfactory. The mixes made from cream melted slowly reached 95 per cent overrun

Figure 2. The Effect of the Rate of Melting Frozen Cream on the Whipping Properities of Ice Cream Mixes.



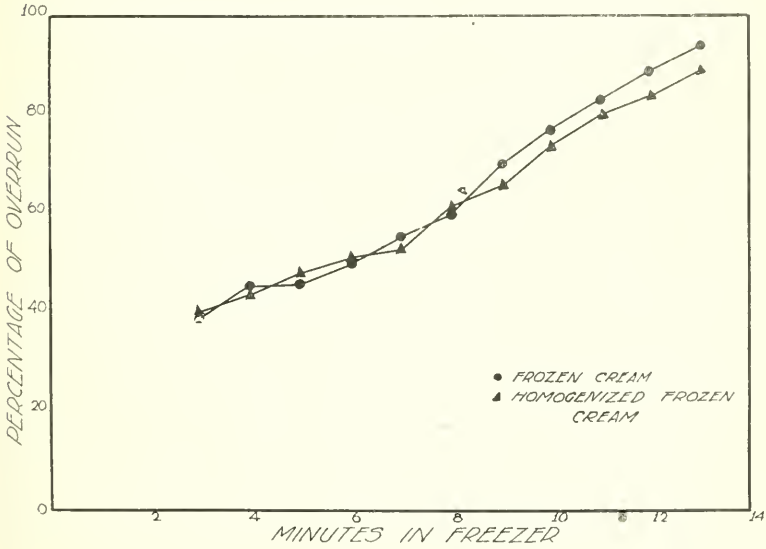
fully a minute quicker than those containing cream melted rapidly. This may have been caused by the fact that rapid melting caused the fat to melt and "oil off". Disturbing the fat phase to this extent may account for the slower whipping of these mixes.

The length of time frozen cream remained in storage had no apparent effect on the whipping time of mixes made from it. This was apparent when mixes containing frozen cream six months old were compared with others containing frozen cream less than one week old. Both groups of mixes whipped in essentially the same time.

Treating Cream Before Freezing

Frozen cream, when melted, was found to be viscous and flaky in nature. The fat globules were present as small granules. The formation of large ice crystals was thought to be the cause of affecting the fat phase, and possibly the stability of the proteins. Therefore, the idea presented itself that if cream were treated so that small ice crystals formed during storage, better results might be obtained. It was thought that homogenization of the cream before freezing, or adding gelatin or sugar, might insure the formation of smaller crystals. Accordingly cream was frozen which previously had been homogenized at 1,000 pounds pressure per square inch. Other lots were frozen containing either 10 per cent sugar (sucrose) or 0.5 per cent gelatin.

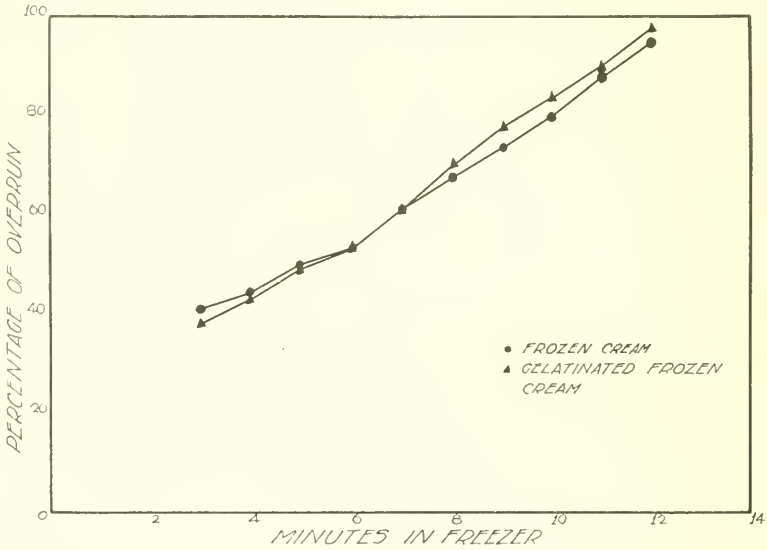
Figure 3. The Effect of Homogenizing Cream Before Freezing on the Whipping Properties of Ice Cream Mixes.



Results with Frozen Homogenized Cream

In Table 1 it may be seen that homogenizing cream before freezing caused the resultant mixes to be of greater viscosity. The size of the fat globules and clumps, however, was little different from measurements made with the control batches. Figure 3 shows that mixes made from frozen homogenized cream reached 90 per cent overrun after approximately one minute more time in the freezer. The higher viscosity of these mixes as compared with ordinary frozen cream mixes was thought to be the cause of their slower whipping. The melted frozen homogenized cream also was more viscous than untreated frozen cream.

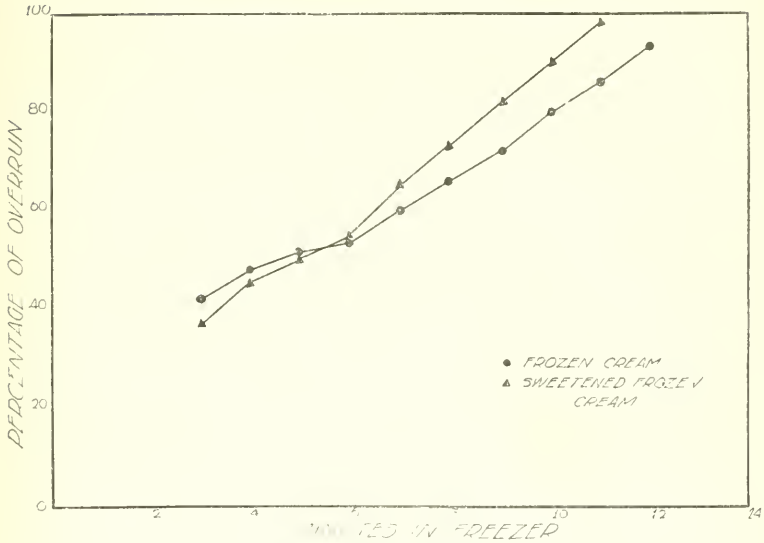
Figure 4. The Effect of Adding 0.5 Per Cent Gelatin to Cream before Freezing on the Whipping Properties of Ice Cream Mixes.



Adding Gelatin Before Freezing Cream

Adding 0.5 per cent gelatin to cream before freezing was of some benefit, as Table 1 and Figure 4 show. Mixes containing frozen gelatinated cream were somewhat more viscous than the controls, but the fat globules, as well as the clumps, were smaller. These mixes whipped somewhat better than those containing plain frozen cream as the source of fat, although the difference was not marked. Evidently gelatin does protect cream to a limited extent against some of the physical changes caused by freezing.

Figure 5. The Effect of Freezing Cream with 10 Per Cent Sugar on the Whipping Properties of Ice Cream Mixes.



Effect of Freezing Cream with Sugar

A marked improvement resulted when cream was frozen with 10 per cent sugar by weight. The data in Table 1 and Figure 5 show a marked difference between frozen sweetened cream mixes and the plain frozen cream mix controls. The viscosity of these mixes was less than that of the controls, and the fat globules and clumps were uniformly smaller. A marked improvement in whipping was found in the frozen sweetened cream mixes, one and one-half minutes less time in the freezer being required to obtain an overrun of 95 per cent.

Other advantages of freezing cream with sugar were apparent. The cream melted much more rapidly than plain frozen cream, due to its lower freezing point. The frozen sweetened cream was low in viscosity, free from noticeable butter granules, and uniform in texture. The product was more like fresh cream than any of the other frozen creams.

Another factor of importance was the improved flavor of frozen sweetened cream mixes over the controls. When samples were submitted to judges so that the identity of the ice cream was unknown, 80 per cent chose the ice cream containing frozen sweetened cream in preference to that made from plain frozen cream. The remaining 20 per cent could see no difference. Possibly the presence of sugar prevents a slight oxidation and in this way partially prevents flavor deterioration.

Observations on Flavor

In this experiment, two different storage rooms were available, one averaging 10° F., and the other —5° F. Frozen cream stored in the

former for four months was equivalent in flavor to that carried six months at the lower temperature. This is in agreement with previously published work (1) (4). Cream of the quality used in this experiment was still suitable for use as the entire source of fat in ice cream mixes after six months storage. These mixes lacked a full, creamy flavor but carried no noticeable off flavor.

It was noticed that when the frozen cream began to go off in flavor, this deterioration increased rapidly in intensity. In view of this fact, the practice of storing cream for periods longer than six months would be unwise. Storage periods shorter than six months are recommended.

DISCUSSION OF RESULTS

No complete explanation can be offered for the slower whipping of frozen cream mixes as compared with the fresh cream mixes. It may be that the higher viscosity and larger fat globules and clumps may not be the cause but may themselves be the result of other changes which also affect the whipping properties of the mixes.

Applying the protein stability test used by Doan (5), the proteins in frozen cream mixes were found to be less stable than in sweet cream mixes. Between 6 and 6.5 c.c. of 92 per cent ethyl alcohol were required to precipitate the proteins in 5 c.c. samples of frozen cream mixes, sweet cream mixes requiring about 7.5 c.c. Further information indicating that freezing tends to affect proteins has been reported by Anderson and Pierce (6).

Of the different methods studied for storing frozen cream, freezing with sugar is to be recommended if the cream is to be used in ice cream. The lower viscosity, better whipping properties, and better flavor of frozen sweetened cream mixes over plain frozen cream mixes, more than offset the slight extra cost of storing cream in this way. In an address, Price (7) reported that preliminary investigations indicate that 15 per cent sugar is the optimum amount to use in frozen cream.

Although only a slight improvement was secured by adding gelatin to pasteurized cream before freezing, the results were all in agreement. This was not true with frozen homogenized cream. Here contradictory results occurred, hence the data reported are truly averages rather than indications of a typical set of results. In no case were variations from the control marked.

An examination of the data shows a relationship between the rate of whipping of mixes and the viscosity. With the exception of the frozen gelatinated cream mixes, the more viscous mixes whipped more slowly. There is a tendency for mixes having the smallest fat globules and clumps to whip most rapidly. The frozen gelatinated cream mixes were again the exceptions. Little difference existed in the size of fat globules and clumps between the frozen homogenized cream mixes and their controls.

The practice followed in some ice cream plants of using frozen cream in combination with fresh sweet cream seems advisable. In this way a better whipping mix results. Also there is less danger of imparting off flavors to the finished product.

SUMMARY AND CONCLUSIONS

1. The storage of frozen cream is a satisfactory method of handling surplus cream for later use in ice cream.

2. The quality of frozen cream depends upon its initial quality, the length of time in storage, and the storage temperature. Holding periods of less than six months and storage temperatures below 0° F. are recommended.

3. The whipping properties of frozen cream mixes were partially lost. They required a longer time in the freezer to reach a definite percentage of overrun than sweet cream mixes and showed a lower maximum overrun.

4. Frozen cream mixes were higher in viscosity than sweet cream mixes and contained slightly larger and more irregular-sized fat globules and clumps.

5. Ice cream mixes containing cream frozen with 0.5 per cent gelatin whipped but little better than plain frozen cream mixes.

6. Homogenizing the cream before freezing did not improve its properties for ice cream making.

7. Freezing cream with 10 per cent sugar was the most satisfactory method studied for storing frozen cream for later use in ice cream. The frozen sweetened cream melted more rapidly than plain frozen cream, was lower in viscosity and much more uniform in body. Ice cream mixes made from frozen sweetened cream were superior in flavor to plain frozen cream mixes, whipped considerably faster in the freezer, were lower in viscosity, and contained smaller fat globules and clumps.

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Publication of this Document Approved by Commission on Administration and Finance

3 m-1-'31. No. 842.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 269 December, 1930

Packaged Ice Cream

By K. E. Wright

There are distinct advantages to be gained by the adoption of the factory prepared and sealed package for ice cream—it is more sanitary, easier to handle, and there is no shrinkage in merchandizing. However, because of a belief that it contains less ice cream and that of a coarser texture, there is a prejudice against this product. This bulletin describes the objections that are raised to the factory filled package of ice cream and suggests methods for improvements.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

PACKAGED ICE CREAM

By K. E. Wright, Assistant Research Professor of Dairy Industry

The Status of the Two Types of Packages

The popularity of the store-filled package is shown in a recent survey (6) in Boston on the subject of consumer preference for packaged ice cream. The results show very strikingly that the overwhelming (three to one) majority of people interviewed expressed a preference for the hand- or store-filled package of ice cream. Of the people stating this preference, the majority gave as the reason that the bulk ice cream was better in quality—tasted better or seemed to have richer flavor or was fresher. Of those who did prefer the plant-filled package, more than half stated that the ease of serving and handling was the reason for their preference. Only a third of this class mentioned sanitary condition as a reason for their choice.

On the other hand, another survey in a different part of the country showed that a slight majority preferred plant-packaged ice cream because it was more sanitary, while the minority chose store-filled packages because of the greater weight received. The fact is significant that one manufacturer who raised his package sales to 50 per cent of his total output experienced a serious drop in sales because the public found that they were not getting as much for their money in the factory-filled product. It is therefore quite evident that it is the difference in quantity and quality and not merely custom that is the cause for the slow adoption of plant-packaged ice cream.

Because of the fact that the dealer has to stand the loss of shrinkage, it is quite reasonable to expect that the method of dipping would be most unsatisfactory to him. As a result, considerable study has been carried on in an effort to decrease the dipping losses incurred in filling packages by hand. In general the results of such investigations have shown that, because of the human element involved, dipping can never be satisfactory as a means of accurate merchandizing unless the practice of weighing is established.

In getting at the faults of factory-packaged ice cream, the amount of the difference in weight of the two types of packages was determined in a survey by Judkins (2), who found the average weight of the dipped pint to be 14.2 ounces and the net average weight of the factory-filled pint to be less than 10 ounces, or a difference of over 4 ounces. This difference still exists, as shown by the Boston survey (6). The difference in quantity is, then, quite obviously at least one very good reason for preferring the dipped to the factory-filled package. The light weight of the factory-filled pint is particularly noticeable when four persons are to be served, as has been the custom from a pint of the store-filled ice cream. Thus because a party of four is a customary number as well as a more typical number than three, it is apparent that it would be advisable to consider this demand.

Further, the greater number of servings made possible through the increase in weight resulting from reduction in overrun makes for greater economy of refrigeration space. This economy of space would allow room for more flavors, which is very desirable according to the Boston survey.

Correction of Weight Objections

Several measures have been adopted by ice-cream manufacturers to overcome the weight faults of the plant-filled package. Many have met the difference in weight by granting a reduction of five cents per pint in price. A large number of plants are now drawing packaged goods at about 70 per cent overrun, although this amount still keeps the weight of a pint at 10.7 ounces net, or more than 3 ounces lighter than the average dipped pint as shown by Judkins (2). Other manufacturers are increasing the fat content and so tend to give more nearly the satisfaction normally experienced in the heavier dipped product. These factors, together with the reduced price, should go a long way toward meeting the weight objection. However, it seems that the recommendations for an overrun of 50 per cent, made in an earlier report of this investigation (8), will simplify the procedure still further. A standard of 50 per cent overrun results in a product equal in weight to a carefully dipped hand-filled package weighing about 12.3 ounces. This weight should be sufficient to meet the quantity objection and would make price cutting unnecessary, a practice which might in itself convey to some the idea of inferior goods. The figures obtained from the Boston survey (6) confirm the importance of the defects in the product which have been the activating motive of this investigation: namely, light weight and poor quality.

Flavor Defects

Although the consumer may not be versed in the exact technical method of describing ice-cream quality, the trade itself has observed that the quality problems of its packaged goods often arise in the form of old flavors and coarse texture. There is also the possibility that because of its light weight, the factory-filled product may be considered poor in quality. The freshness of flavor in the factory-filled product as compared with the dipped product lies with the dealer and to some extent with the manufacturer. The latter should not permit the dealer to become overstocked and should also assist the dealer in keeping his stock rotated so that the oldest product is sold first, as is essential in any well regulated hardening room.

Texture of Packaged Ice Cream

One very possible source of poor texture lies in the fact that a smooth product can become coarse by repeated heat shock. It has been observed in the industry that by the time the package has been transferred from the hardening room to the truck and then to the dealer's cabinet, it may often reach a temperature of 15° F. if the cabinet lids have been frequently removed. Then there follows the daily rechilling and warming, with a

range of about 10° F., until the package is sold. The above conditions, however, are coming to be a less serious factor with the general replacement of ice and salt by electric refrigeration and the use of dry ice in transportation. Commercial practice has also shown that dry ice transportation relieves the necessity of returning unsold goods to the hardening room each day and so eliminates the possibility of one or more heat shocks.

As a result of observations made of packaging operations, the conclusion was reached that the principal source of poor texture was the conditions surrounding the initial crystallization of the ice cream, particularly those affecting the temperature of the package before it is placed in the hardening room. However, in order to give proper emphasis to the importance of the initial hardening temperature, it is necessary to modify certain opinions concerning the importance of the rate of freezing in the freezer.

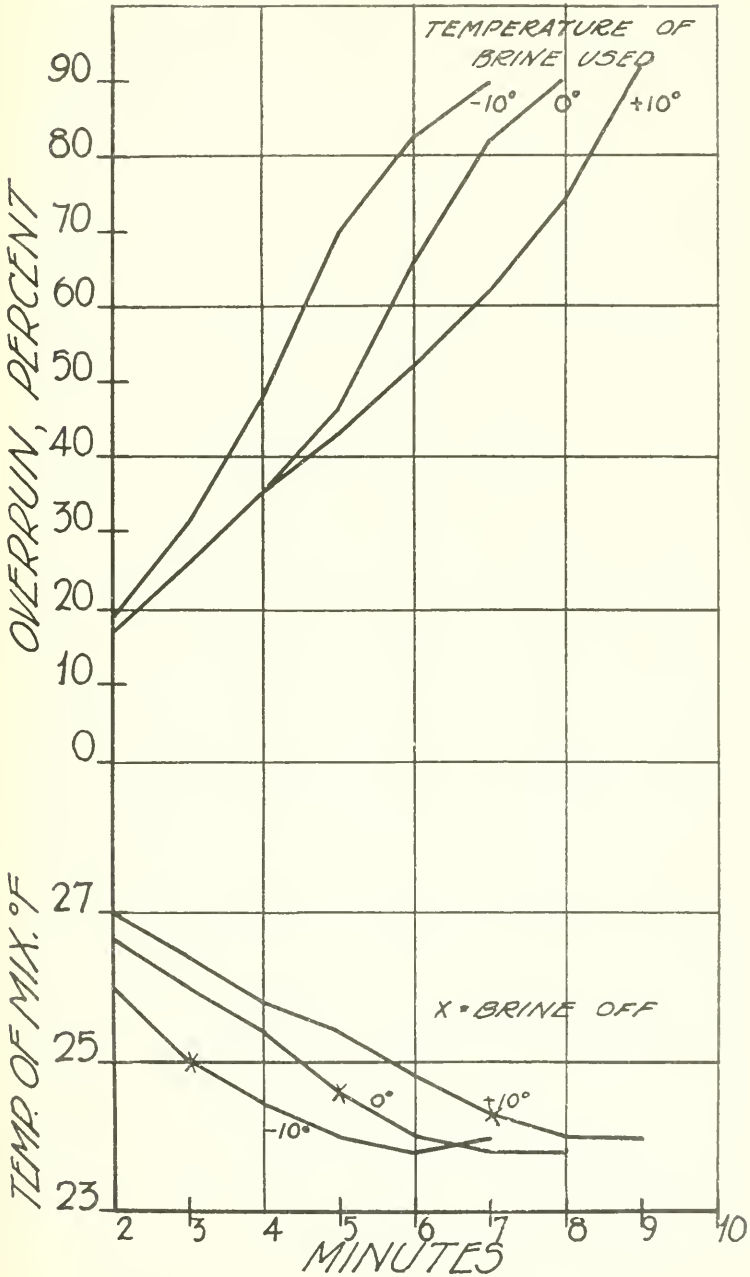
Initial Hardening Temperature Important

Although it has been regarded that stiffness of mix and the rate of freezing are important, no definite range has been fixed for these factors other than their practical limitations. The effect of brine temperature on the rate of cooling of the mix is shown in Figure 1. It will be noted that the difference of 20° F. in brine temperature caused the mix to cool but twice as fast, or about 1° F. per minute at the point where the first crystallization would take place. A comparison of ice cream frozen with brine of the two temperatures showed that there was no appreciable difference in texture if samples were drawn from the freezer at the same consistency. It is evident that low temperatures were far more significant in shortening the time of freezing than in improving the texture. Even as a means of hastening the process of freezing, the use of extremely low brine temperatures is questionable, for unless the brine is shut off at the exact fraction of a second required, the mix may be so stiff that extra whipping will be necessary to prepare it for drawing.

The question then remains, what is the most significant factor to be considered? The drawing temperature of ice cream is extremely important as evidenced by the fact that most of the current trade literature emphasizes the significance of a low drawing temperature or a stiff mix in referring to texture. In this investigation numerous series of samples were frozen to varying degrees at the freezer and then were chilled in the hardening room. As the temperature was lowered in the freezer to a rather definite "critical point" below the freezing point of the mix, a gradual improvement in the texture of the finished ice cream was noted. Below this "critical point" there was no appreciable improvement. The maximum temperature allowable before hardening was about 25.5° F. for the mix used in this study, which contained 12 per cent fat, 10 per cent serum solids and 15 per cent sugar, with 0.35 per cent of 250 Bloom gelatin.

The "critical point" temperature is therefore the point at which the maximum number of crystals are formed and are consequently small, thus making for a smooth texture. In terms of crystallization this point appears to be the point of saturation favorable to the greatest number

Fig. 1. Influence of Brine Temperature on Overrun and Temperature of Mix During Freezing Process.



of crystal centers, known as the labile range. Since the "critical point" refers only to the maximum allowable temperature of the product when placed in the hardening room, it is essential to draw the ice cream at a temperature low enough to allow for a slight rise in temperature during handling. The neglect of this point is very probably the cause of poor texture in many instances. Observations in commercial plants as well as in the laboratory showed clearly that when ice cream was allowed to become "soupy" or softer than mix at the "critical point" temperature, the texture was always coarse.

Observations made by Turnbow (5) are in close agreement with the above conclusions. His results based upon microphotographic observations showed that there was no enlarging of crystals in ice cream when initially frozen to about 26° F. or lower for a similar mix. Thus his data correspond to observations made independently in this study. From the results of the investigations at this Station (8) and those of Turnbow, the indication is that the small size of the crystals is primarily dependent upon fairly rapid supercooling to the labile or "critical point" which is the optimum range for spontaneous formation of crystal centers. Thus the crystals formed above the "critical point" are large because in the metastable range—above the labile but still below the freezing point—there are but few nuclei formed. Therefore it is highly essential, and here is the answer to our question, that the temperature of a semi-soft ice cream should not rise above the labile or "critical point" because centers or nuclei formed will redissolve, reducing the number of nuclei and thus making for large rather than small crystal formation.

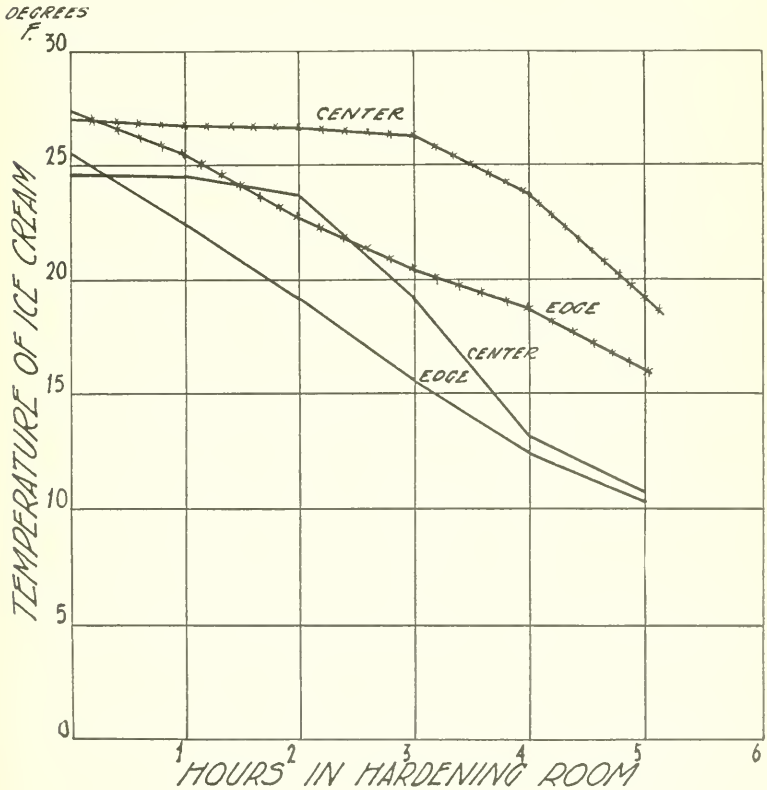
As would be expected from the foregoing, carelessness in allowing too much time to elapse, with consequent warming of the mix, between the drawing of the package and its entry into the hardening room is a common cause of coarseness. The failure to chill hoppers also contributes to warming of the product and so is another item influencing texture, as is also the fact that some packaging machines do not function as rapidly as desired with mix of the proper stiffness. It was also observed that in filling pans for brick packages, the mix became too soft in filling third portions because of the long time required to empty the freezer. Still another condition favoring the development of coarse ice cream arises whenever the scraper blades are very dull or out of alignment. Here it was found that the overrun was reached before the mix was sufficiently cooled.

Those who would have their Dixie cups or similar containers thought of as sample portions of their goods should use extra care in filling these containers by not allowing the mix to become too soft, and so avoid coarse texture. Because of their small size, these cups appear to warm up faster. Here, if the rate of cooling in the hardening room was very significant, the rapid freezing possible because of their size would in turn also cause a smooth texture to result.

Some have offered the opinion that the paper container at room temperature was sufficiently warm in itself to warm the product enough to affect the texture. Attempts to verify this in the laboratory showed that this effect alone was not serious. It is estimated that 400 calories of heat are taken up by filling a pint carton of ice cream from the freezer. This is for a carton at room temperature, weighing about 40 grams with an

assumed specific heat of 0.5 calories per gram. The approximate theoretical rise in temperature of a 10-ounce quantity of ice cream would be about 3.6° F. or enough to melt about 5 grams of ice. However, because of the extremely slow conductivity of a semi-frozen ice cream, only a thin layer next to the carton is affected. It is probable that this melted film is the cause of a slight shrinkage that is experienced in packaging a given lot of ice cream from the freezer. Although this film of melted cream would be expected to form an icy outside layer, it is not noticed by the consumer because it is the first to melt. The slow rate of heat transfer which takes place in a pint size package is shown in Figure 2, made from temperature readings taken from the inner side of the carton and at the center of pint samples drawn at the temperatures shown by the first center temperature readings.

Fig. 2. The Rate of Cooling of Pint Packages of Ice Cream in the Hardening Room at 4° F.



From this same graph it will be noted that more than one hour was required for the cold to reach the center of the pint package. This very long cooling period also points very strongly to the conclusion that the

initial crystal condition before hardening is important, otherwise the center of the package would be noticeably rougher than the outside. Along with this fact the results of the following experiments may be considered. A pint package of cream from the freezer was placed in the hardening room immediately after drawing, along with another sample enclosed in an insulated jacket in which it is evident that the cooling would be very slow. The fact that no difference in texture could be observed as a result of the two methods of hardening again points to the idea that the crystal structure is determined to a very large extent before hardening.

Influence of Fat on Texture

In addition to the enriching value of butterfat as earlier mentioned, its effect in improving texture is probably as permanent as any single factor. The padding effect of the fat against the ice crystals is so great that it largely covers up the difference in crystal size. It is possible that the fat actually retards the crystal growth. An example of this action of fat is shown by the great difference in the texture of a sherbet frozen by the old brine freezer and in the new continuous freezer, as compared with the far less noticeable difference in texture of a 14 per cent fat ice cream frozen by the two types of freezers.

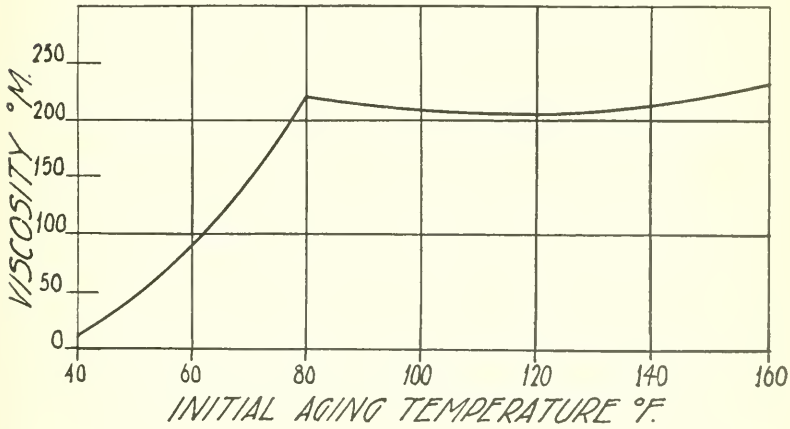
Effect of Gelatin on Texture

A small amount of gelatin is very frequently used to impart greater smoothness to ice cream. The gelatin combines with a portion of the water to make it less available to crystal formation and at the same time the gel so formed protects the crystals that do form so as to give greater smoothness.

In the attempt to improve texture, gelatin was given special study (9). The use of 0.35 per cent of high-strength gelatin (250 Bloom) gave a product of the desired smoothness, while 0.4 per cent gelatin imparted a slightly soggy body to the product. The influence of gelatin is closely associated with aging, inasmuch as mixes containing gelatin are the only ones characterized by a marked increase in viscosity. Starting with the theory that gelatin gel particles are built up from single molecules of gelatin which cause development of viscosity according to the rate of cooling, experiments were conducted which resulted in an explanation for the behavior of gelatin in the aging of ice cream. Briefly, the aging of gelatin in ice cream is the process of the gelatin particle or crystal formation and subsequent gel structure growth. Very rapid cooling of the ice cream mix as normally conducted is unfavorable to crystal growth because the gelatin is in a state of a supercooled melt which does not allow for molecular activity. Thus solidification cannot take place. In this condition of retarded molecular activity there is no heat of fusion liberated. Without this liberation there cannot be an equilibrium between the energy produced and the change of state. However, a slow cooling just below the melting point of gelatin results in a subdued molecular activity, permitting the molecules to collide and adhere to form particles

and aggregates, or the solid state. Thus the aggregation at the warmer temperature (below 98° F., the melting point of gelatin according to Oakes and Davis (3)), results in particles large enough to impart additional viscosity to the mix as well as apparent viscosity due to the adhesion of these particles. From this conception of gel formation it is not difficult to see how mixes of various viscosities may be made simply by controlling the rate of cooling. Experimental evidence of these principles is shown by cooling portions of skim milk solutions of gelatin from various initial temperatures to 40° F. by holding the portions in a cooler at this temperature for 24 hours. The viscosity results obtained from such a series are shown in Figure 3. The graph shows that there is a marked increase in viscosity as the initial aging temperature is raised to over 80° F. These and all other viscosity results obtained were taken after vigorous agitation was given to the material to destroy apparent viscosity structure.

Fig. 3. Effect of Initial Aging Temperatures on Viscosity of 0.5 Per Cent Gelatin in Skim Milk.



Various investigators have implied that whatever the apparent viscosities might be for a given mix, it could always be reduced to the same basic viscosity. This is not the case in view of the above observations. The permanency of these various basic viscosities due to temperature is further shown by their effect on melting ice cream so treated, as illustrated in the photograph, Figure 4. Therefore, if the occlusion of water by gelatin in the mix cooled in the usual manner is a cause of smoother texture, then the still greater occlusion of water as shown by the much greater viscosity developed in samples slowly cooled should cause still smoother texture, according to the writer's previous work (9).

An idea of the improvement obtained by this method may be secured from the following experimental results. A normally aged sample of ice cream was compared with a sample aged by slow cooling from 80° F.

7. Because of the low overrun required in packaged goods, it was found necessary to retard the overrun of easily whipped mixes in order to permit the drawing of the mix at the proper consistency. The substitution of butter for a part of the cream was found to be the most effective practical means of effecting a low constant overrun.

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Publication of this Document Approved by Commission on Administration and Finance

3 m-1-'31. No. 844

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 270 December, 1930

Meteorological Records

A Forty-Year Summary

1889—1928

BY C. I. GUNNESS

OBSERVATORY

Latitude 42° 23′ 48.5″ N. Longitude 72° 31′ 10″ W.

Height of barometer above ground, 36 ft. Above sea level, 253.5 ft.

Height of wind instruments, 67 ft. Time used, 75th Mer.

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AGRICULTURAL EXPERIMENT STATION
AMHERST, MASS.

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METEOROLOGICAL RECORDS
A FORTY-YEAR SUMMARY, 1889—1928

By C. I. Gunness, Meteorologist[1]

Location and Equipment

The meteorology observatory is now located on the third floor in Stockbridge Hall. It was moved to this location from South College on June 12, 1928, where it had been located since 1889. The records up to June 12, 1928, were, therefore, taken at the old location; between June 12 and December 31, 1928, they were taken at the new location.

In the old location the observatory was in the tower of South College, about 50 feet above the ground. The base of the tower is 223 feet above sea level and the top of the tower is 72 feet above the ground. The exposure is good in all directions. The anemometer, wind vane, and sunshine recorder were mounted from 3 to 5 feet above the tower with the recording apparatus in the room below. The thermometer shelter and rain gauges were on the campus about 300 feet southwest from the tower and on slightly lower ground. The rain gauges were about 2 feet above ground and 218 feet above sea level.

In the present location the anemometer, wind vane, and sunshine recorder are located from 4 to 7 feet above the roof of Stockbridge Hall. The roof is 60 feet above the ground with good exposure. The thermometer shelter and rain gauges are about 300 feet west from Stockbridge Hall.

The same equipment is used in the new location as was used in the old, except as noted below. The standard barometer is of United States Weather Bureau pattern. A Draper mercury-column type, recording barometer and a Friez electrical sunshine recorder are used. A four-cup anemometer was used until January 1, 1930, when a three-cup anemometer was installed. The records of sunshine, wind velocity, and rainfall are recorded on a triple register. A United States Weather Bureau gauge is used in determining precipitation; and a tipping bucket, electrical recording gauge, in determining the time and rate. The latter gauge is now located on the roof of the Agricultural Engineering building, and serves to measure melted snow as well as rain. The wind direction is recorded on a Draper anemoscope. A Friez hygro-thermograph was installed in April, 1929, in place of the Draper recording thermometer used until that time.

On January 1, 1904, the time of making observations was changed from 7 a.m., 2 p.m. and 9 p.m. to 8 a.m. and 8 p.m., so as to conform with the practice of the United States Weather Bureau. This change should be noted in comparing the dew point and relative humidity before and after that date. Other data are probably not affected by the change.

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[1]Head of the Department of Agricultural Engineering.

Mean Barometer

[Readings are reduced to freezing and sea level.]

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	30.11	30.24	29.84	29.80	29.92	29.96	29.91	30.01	30.00	30.05	30.04	30.14	30.00
1890 . .	30.19	30.10	29.99	30.10	29.96	29.98	30.02	30.00	30.12	29.88	30.01	30.01	30.03
1891 . .	29.96	30.04	30.10	29.92	29.98	29.92	29.99	29.96	30.11	30.03	30.12	30.08	30.02
1892 . .	29.96	30.11	29.90	29.97	29.94	29.92	29.99	30.02	30.10	29.90	29.99	30.01	29.98
1893 . .	29.95	30.11	30.06	30.09	29.90	30.06	29.97	30.00	30.06	30.13	30.12	30.12	30.05
1894 . .	30.18	30.16	30.09	30.05	30.00	30.00	30.01	30.03	30.14	30.02	30.08	30.15	30.08
1895 . .	30.05	29.92	30.00	30.12	30.10	30.17	30.03	30.02	30.10	30.08	30.19	30.15	30.08
1896 . .	30.16	29.86	29.99	30.14	29.98	29.95	29.97	29.99	30.00	30.01	30.14	30.14	30.03
1897 . .	30.04	30.06	30.04	30.04	29.92	29.90	29.94	29.94	30.09	30.12	30.03	30.04	30.01
1898 . .	29.98	30.05	30.20	29.93	29.94	29.95	30.02	29.96	30.01	30.09	30.01	29.96	30.01
1899 . .	30.11	29.98	29.94	30.04	30.00	29.98	29.93	29.98	30.02	30.19	30.01	30.03	30.02
1900 . .	30.03	29.97	29.95	29.96	29.91	29.91	29.91	29.99	30.04	30.15	29.99	30.03	29.98
1901 . .	29.95	29.79	29.90	29.97	29.88	29.95	29.93	30.02	30.03	30.08	29.93	30.03	29.96
1902 . .	30.04	29.78	29.91	29.88	29.84	29.84	29.96	29.92	30.04	30.03	30.06	30.06	29.95
1903 . .	29.91	29.98	30.20	29.87	29.94	29.94	29.88	30.00	30.10	30.00	30.01	29.97	30.00
1904 . .	30.08	30.11	30.11	29.97	30.02	30.02	29.98	30.03	30.08	30.08	29.95	30.02	30.03
1905 . .	30.08	30.12	30.12	29.85	29.93	29.93	29.95	29.98	30.05	30.10	30.01	30.08	29.94
1906 . .	30.09	30.20	30.09	29.98	29.94	29.94	29.98	30.02	30.09	30.09	30.04	30.12	30.05
1907 . .	30.23	30.09	30.08	29.88	29.93	29.93	29.87	30.00	30.02	30.05	30.05	30.02	30.02
1908 . .	29.97	30.08	30.10	29.92	30.03	30.03	30.04	30.03	30.10	30.17	30.01	30.04	30.04
1909 . .	30.15	29.96	29.82	30.06	29.94	29.97	29.91	30.02	30.11	30.03	30.16	29.89	30.01
1910 . .	30.11	30.07	30.08	29.97	29.96	29.92	29.89	30.07	30.10	30.01	29.80	30.03	30.00
1911 . .	30.12	30.12	29.99	30.14	30.03	29.94	29.99	30.02	30.06	30.11	30.01	30.15	30.06
1912 . .	30.02	29.93	30.13	29.99	29.96	29.99	29.98	29.95	30.07	30.06	30.00	30.01	30.01
1913 . .	30.10	30.01	30.11	30.02	29.99	30.00	29.94	30.03	30.13	29.97	30.13	30.01	30.04
1914 . .	29.96	30.13	30.00	30.03	30.04	29.95	29.98	30.01	30.13	30.10	30.07	30.18	30.05
1915 . .	30.12	30.12	29.83	30.03	29.91	30.02	29.92	29.98	30.05	30.08	29.99	29.95	29.99
1916 . .	30.18	30.01	29.96	29.92	29.91	29.95	29.98	29.98	30.04	30.13	30.10	29.93	30.01
1917 . .	30.01	29.93	30.06	29.93	29.81	30.00	29.95	30.01	30.11	30.05	30.07	30.22	30.01
1918 . .	29.88	30.06	29.99	30.07	30.06	29.92	29.97	30.03	30.03	30.12	30.02	30.13	30.02
1919 . .	30.01	29.96	30.12	30.03	29.98	30.13	29.97	29.94	30.02	30.12	30.08	30.11	30.03
1920 . .	30.17	29.98	29.97	29.82	30.06	29.95	29.96	30.06	29.99	30.07	30.13	29.96	30.00
1921 . .	30.11	30.08	30.15	30.06	30.01	29.94	29.98	30.07	30.03	29.97	30.08	30.01	30.04
1922 . .	30.18	30.12	30.10	30.04	30.02	29.96	30.02	29.99	30.11	29.99	30.02	30.15	30.06
1923 . .	30.08	30.12	30.02	29.96	29.95	29.85	30.00	29.96	30.11	30.10	30.07	30.04	30.02
1924 . .	30.14	30.07	29.77	29.95	29.85	29.93	29.95	29.97	30.09	30.21	30.06	30.13	30.01
1925 . .	30.20	30.06	30.07	30.03	29.94	29.96	29.92	30.06	30.05	29.98	30.09	29.90	30.02
1926 . .	29.99	29.87	29.93	29.93	29.88	29.92	29.96	30.00	30.14	29.94	30.11	30.10	29.98
1927 . .	30.13	30.04	30.10	30.06	29.92	29.98	29.97	30.00	30.02	29.97	30.09	30.04	30.03
1928 . .	29.96	30.07	29.88	29.98	29.92	29.91	29.95	30.03	30.06	30.11	30.00	30.10	30.00
Mean .	30.07	30.03	30.02	29.99	29.95	29.96	29.97	30.00	30.07	30.06	30.05	30.06	30.02

Range of Barometer (in Inches)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	1.62	1.51	1.58	1.16	.75	.97	.68	.66	.98	.96	1.31	1.75	1.81
1890 . .	1.50	1.35	1.08	1.08	.81	.58	.63	1.10	.69	1.09	.98	1.20	1.76
1891 . .	1.93	1.36	1.21	1.42	.79	.53	.74	.61	.73	1.11	1.56	1.22	2.05
1892 . .	1.38	1.65	1.16	1.02	.96	.84	.97	.55	.96	.98	1.00	1.01	1.65
1893 . .	1.53	1.83	1.27	1.25	1.16	.67	.68	.93	.81	1.37	1.16	1.53	1.92
1894 . .	1.89	1.65	1.04	.86	.93	.75	.57	.44	1.11	1.19	1.22	1.23	2.01
1895 . .	1.46	1.88	1.24	1.40	.84	.66	.51	.53	.68	1.09	1.47	1.78	2.27
1896 . .	.97	1.77	1.52	.96	.75	.83	.79	.59	.85	1.10	1.23	1.57	2.22
1897 . .	1.57	1.15	1.74	1.10	.76	.55	.72	.61	.73	1.12	1.48	1.42	1.76
1898 . .	1.43	1.63	1.17	.86	.76	.95	.81	.60	.82	1.19	1.25	1.39	1.75
1899 . .	1.70	1.41	1.54	.90	.60	.59	.51	.56	.88	.76	1.10	1.58	1.82
1900 . .	1.58	1.89	1.52	1.01	.99	.67	.73	.53	1.03	1.07	1.71	1.53	1.89
1901 . .	1.68	.97	1.17	1.19	.77	.61	.59	.51	1.00	1.22	1.14	1.13	1.68
1902 . .	1.49	1.41	1.55	1.04	.94	1.27	.58	.67	.78	1.25	1.12	1.34	1.89
1903 . .	1.49	1.55	1.19	1.15	.85	.97	.57	.77	.78	1.08	1.32	1.56	1.77
1904 . .	1.50	1.36	1.58	1.00	.75	.81	.73	.73	1.20	1.23	1.84	1.43	2.23
1905 . .	1.37	1.28	.89	1.15	.85	.83	.58	.72	.66	1.16	1.22	1.53	1.64
1906 . .	1.53	1.28	1.64	1.05	1.08	.77	.90	.72	1.03	1.41	1.05	1.30	1.70
1907 . .	1.34	1.27	1.39	1.42	.67	.71	.76	.71	.91	1.24	1.59	1.46	1.79
1908 . .	1.73	1.89	1.22	1.35	1.11	.65	.66	.68	.73	1.17	1.14	1.31	1.97
1909 . .	1.64	1.63	1.52	1.14	0.82	.68	.88	.97	.80	.97	1.24	1.54	1.91
1910 . .	1.76	1.40	1.11	.90	1.02	.83	.57	.82	.57	1.05	1.02	1.44	1.76
1911 . .	1.50	1.09	1.77	1.14	.97	.69	.74	.76	.85	1.04	1.24	1.20	1.77
1912 . .	1.60	1.75	1.43	1.32	.86	.64	.89	.77	.75	.87	1.17	1.46	1.98
1913 . .	2.18	.88	1.92	1.06	.87	.80	.65	.72	.83	1.38	1.65	1.34	2.33
1914 . .	1.45	1.50	2.10	1.06	1.01	.65	.55	.55	.84	1.00	1.32	1.52	2.31
1915 . .	1.26	1.31	.85	.99	.83	.64	.74	59	1.03	.83	1.29	1.67	1.73
1916 . .	1.17	1.84	1.25	.94	1.10	.52	.84	.76	.87	1.03	1.53	1.51	1.88
1917 . .	1.38	1.50	1.09	1.09	.80	.58	.56	.70	1.05	1.11	1.08	1.66	1.93
1918 . .	1.70	1.82	1.01	.96	.99	.93	.53	.76	.73	1 01	1.55	1.19	1.86
1919 . .	1.35	1.16	1.72	.72	.70	.73	.78	.64	.83	1.06	1.16	1.26	1.72
1920 . .	1.58	1.84	1.52	.94	.73	.78	.72	.78	1.02	1.13	1.27	1.25	2.02
1921 . .	1.50	1.09	1.01	1.05	.72	.75	.56	.74	.79	1.15	1.02	1.43	1.57
1922 . .	1.78	1.25	1.31	1.05	.95	.81	.56	.70	.79	.99	1.03	1.02	1.78
1923 . .	1.41	1.10	1.63	1.27	.85	.87	.73	.72	.71	.84	1.28	1.51	1.55
1924 . .	1.44	1.13	.98	.98	.98	.78	.72	.73	1.10	.90	1.38	1.40	1.58
1925 . .	1.57	1.22	1.22	.96	.89	.74	.52	.70	.95	1.43	1.59	1.11	1.68
1926 . .	1.22	1.20	1.41	.99	.98	.70	.83	.65	.62	1.47	1.21	1.12	1.62
1927 . .	1.70	1.06	1.09	1.00	.94	.69	.57	.66	.95	1.24	1.71	1.64	1.98
1928 . .	1.71	1.40	1.28	1.09	.88	.65	.57	.68	.70	1.00	1.10	1.41	1.83
Mean .	1.54	1.43	1.35	1.08	.88	.74	.68	.69	.85	1.11	1.29	1.40	1.86

Maximum Barometer

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	30.82	30.97	30.66	30.54	30.40	30.54	30.35	30.45	30.40	30.52	30.67	30.96	30.97
1890 . .	30.94	30.72	30.56	30.57	30.32	30.28	30.27	30.28	30.42	30.41	30.35	30.61	30.94
1891 . .	30.62	30.69	30.57	30.56	30.44	30.22	30.37	30.27	30.45	30.67	30.74	30.55	30.74
1892 . .	30.67	30.72	30.45	30.53	30.43	30.39	30.50	30.24	30.42	30.43	30.44	30.53	30.72
1893 . .	30.61	30.83	30.63	30.65	30.32	30.36	30.25	30.30	30.45	30.65	30.70	30.92	30.92
1894 . .	30.77	30.89	30.57	30.52	30.50	30.33	30.31	30.24	30.63	30.42	30.73	30.53	30.89
1895 . .	30.61	30.44	30.52	30.70	30.55	30.51	30.33	30.29	30.41	30.67	30.73	30.83	30.83
1896 . .	30.56	30.49	30.62	30.60	30.48	30.42	30.49	30.39	30.40	30.62	30.86	30.94	30.94
1897 . .	30.77	30.70	30.88	30.61	30.36	30.28	30.33	30.18	30.40	30.67	30.60	30.60	30.88
1898 . .	30.61	30.64	30.76	30.34	30.33	30.35	30.44	30.26	30.41	30.46	30.53	30.52	30.76
1899 . .	30.92	30.53	30.49	30.39	30.29	30.25	30.24	30.31	30.47	30.50	30.54	30.66	30.92
1900 .	30.67	30.75	30.59	30.48	30.38	30.19	30.16	30.25	30.35	30.52	30.64	30.51	30.75
1901 . .	30.69	30.34	30.43	30.52	30.20	30.24	30.29	30.28	30.51	30.66	30.37	30.58	30.69
1902 . .	30.66	30.27	30.50	30.28	30.43	30.46	30.29	30.26	30.38	30.52	30.48	30.75	30.75
1903 . .	30.62	30.48	30.65	30.46	30.54	30.39	30.17	30.42	30.42	30.40	30.70	30.60	30.70
1904 . .	30.90	30.67	30.96	30.50	30.37	30.35	30.26	30.42	30.62	30 57	30.57	30.54	30 96
1905 . .	30.70	30.62	30.60	30.37	30.38	30.19	30.15	30.27	30.41	30.58	30.63	30.86	30.86
1906 . .	30.78	30.95	30.92	30.45	30.49	30.35	30.46	30.38	30.50	30.63	30.42	30.77	30.95
1907 . .	30.75	30.78	30.59	30.41	30.34	30.22	30.18	30.35	30.39	30.60	30.59	30.45	30.78
1908 . .	30.59	30.83	30 59	30.52	30.31	30.40	30.26	30.31	30.45	30.59	30.45	30.61	30.83
1909 . .	30.75	30.53	30.36	30.60	30.29	30.26	30.27	30.39	30.52	30.52	30.74	30.58	30.75
1910 . .	30.87	30.80	30.50	30.40	30.40	30.24	30.18	30.37	30.34	30.47	30.40	30.78	30.87
1911 . .	30.66	30.64	30.72	30.71	30.40	30.24	30.26	30.30	30.41	30.59	30.48	30.57	30.72
1912 . .	30.59	30.47	30.70	30.62	30.31	30.31	30.35	30.29	30.37	30.46	30.50	30.61	30.70
1913 . .	30.73	30.44	30.88	30.56	30.39	30.43	30.19	30.41	30.58	30.52	30.72	30.47	30.88
1914 . .	30.53	30.68	30.57	30.43	30.50	30.29	30.21	30.26	30.53	30.60	30.78	30.69	30.78
1915 . .	30.56	30.58	30.37	30.51	30.28	30.23	30.22	30.28	30.37	30.41	30.48	30.52	30.58
1916 . .	30.64	30.60	30.44	30.27	30.32	30.13	30.35	30.27	30.53	30.53	30.55	30.47	30.64
1917 .	30.74	30.43	30.53	30.33	30.27	30.33	30.22	30.29	30.54	30.40	30.54	30.86	30.86
1918 . .	30.51	30.70	30.46	30.55	30.50	30.24	30.22	30.48	30.42	30.57	30.60	30.70	30.70
1919 . .	30.68	30.43	30.92	30.37	30.44	30.51	30.37	30.28	30.39	30.61	30.53	30.67	30.92
1920 . .	30.99	31.05	30.55	30.14	30.45	30.32	30.24	30.40	30.37	30.39	30.62	30.60	31.05
1921 . .	30.90	30.52	30.65	30.56	30.42	30.27	30.21	30.35	30.33	30.48	30.52	30.79	30.90
1922 . .	30.70	30.60	30.63	30.43	30.48	30.21	30.23	30.33	30.46	30.49	30.39	30.69	30.70
1923 . .	30.84	30.66	30.78	30.61	30.29	30.19	30.40	30.20	30.45	30.42	30.62	30.81	30.84
1924 . .	30.77	30.75	30.21	30.41	30.21	30.34	30.23	30.28	30.65	30.60	30.58	30.59	30.77
1925 . .	30.76	30.44	30.64	30.53	30.34	30.32	30.16	30.42	30.59	30.53	30.67	30.47	30.76
1926 . .	30.53	30.40	30.60	30.34	30.36	30.29	30.33	30.40	30.41	30.47	30.55	30.62	30.62
1927 . .	31.00	30.45	30.49	30.46	30.47	30.30	30.30	30.36	30.44	30.37	30.73	30.76	31.00
1928 . .	30.61	30.73	30.48	30.47	30.38	30.13	30.24	30.34	30.38	30.55	30.53	30.53	30.73
Mean .	30.71	30.63	30.60	30.48	30.38	30.31	30.28	30.32	30.45	30.53	30.58	30.65	30.81

Minimum Barometer

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	29.20	29.46	29.08	29.38	29.65	29.57	29.67	29.79	29.42	29.56	29.36	29.21	29.08
1890 . .	29.44	29.37	29.48	29.49	29.51	29.70	29.64	29.18	29.73	29.32	29.37	29.41	29.18
1891 . .	28.69	29.33	29.36	29.14	29.65	29.69	29.63	29.66	29.72	29.56	29.18	29.33	28.69
1892 . .	29.29	29.07	29.29	29.51	29.47	29.55	29.53	29.69	29.46	29.45	29.44	29.52	29.07
1893 . .	29.08	29.00	29.36	29.40	29.16	29.69	29.57	29.37	29.64	29.28	29.54	29.39	29.00
1894 . .	28.88	29.24	29.53	29.66	29.57	29.58	29.74	29.80	29.52	29.23	29.51	29.30	28.88
1895 . .	29.17	28.56	29.28	29.30	29.71	29.85	29.82	29.76	29.73	29.58	29.26	29.05	28.56
1896 . .	29.59	28.72	29.10	29.64	29.73	29.59	29.70	29.80	29.55	29.52	29.63	29.37	28.72
1897 . .	29.20	29.55	29.14	29.51	29.60	29.63	29.61	29.57	29.67	29.55	29.12	29.18	29.12
1898 . .	29.18	29.01	29.59	29.48	29.57	29.40	29.63	29.66	29.59	29.27	29.28	29.13	29.01
1899 . .	29.22	29.12	28.95	29.49	29.69	29.66	29.63	29.75	29.56	29.74	29.44	29.10	29.10
1900 . .	29.08	28.86	29.06	29.47	29.39	29.51	29.42	29.72	29.32	29.42	28.93	28.98	28.86
1901 . .	29.01	29.37	29.26	29.33	29.43	29.63	29.70	29.76	29.51	29.44	29.23	29.42	29.01
1902 . .	29.17	28.86	28.95	29.24	29.49	29.24	29.61	29.59	29.60	29.27	29.36	29.41	28.86
1903 . .	29.13	28.93	29.46	29.31	29.69	29.42	29.60	29.65	29.69	29.32	29.38	29.04	28.93
1904 . .	29.40	29.31	29.38	29.50	29.62	29.54	29.53	29.69	29.42	29.28	28.73	29.11	28.73
1905 . .	29.33	29.34	29.71	29.22	29.53	29.36	29.57	29.55	29.75	29.42	29.41	29.33	29.22
1906 . .	29.25	29.67	29.28	29.40	29.41	29.58	29.56	29.66	29.47	29.22	29.37	29.47	29.25
1907 . .	29.41	29.51	29.29	28.99	29.69	29.51	29.42	29.64	29.48	29.36	29.00	29.05	28.99
1908 . .	28.86	28.94	29.37	29.27	29.20	29.75	29.69	29.66	29.72	29.42	29.31	29.30	28.86
1909 . .	29.11	28.90	28.84	29.46	29.47	29.58	29.39	29.42	29.72	29.55	29.50	29.04	28.84
1910 . .	29.11	29.40	29.39	29.50	29.38	29.41	29.61	29.55	29.77	29.42	29.38	29.34	29.11
1911 . .	29.16	29.55	28.95	29.57	29.43	29.55	29.52	29.54	29.56	29.55	29.24	29.37	28.95
1912 . .	28.99	28.72	29.27	29.30	29.45	29.67	29.46	29.52	29.62	29.59	29.33	29.15	28.72
1913 . .	28.55	29.56	29.26	29.50	29.52	29.63	29.54	29.69	29.75	29.14	29.07	29.13	28.55
1914 . .	29.08	29.18	28.47	29.37	29.49	29.64	29.66	29.71	29.69	29.60	29.46	29.17	28.47
1915 . .	29.30	29.27	29.52	29.52	29.45	29.60	29.48	29.69	29.34	29.58	29.19	28.85	28.85
1916 . .	29.47	28.76	29.19	29.34	29.22	29.61	29.51	29.51	29.66	29.50	29.02	28.96	28.76
1917 . .	29.36	28.93	29.44	29.24	29.47	29.75	29.66	29.59	29.49	29.29	29.46	29.20	28.93
1918 . .	28.84	28.88	29.45	29.59	29.51	29.31	29.69	29.72	29.69	29.56	29.05	29.51	28.84
1919 . .	29.33	29.27	29.20	29.65	29.74	29.78	29.59	29.64	29.56	29.55	29.37	29.41	29.20
1920 . .	29.41	29.21	29.03	29.20	29.72	29.54	29.52	29.62	29.35	29.26	29.35	29.35	29.03
1921 . .	29.40	29.43	29.64	29.51	29.70	29.52	29.65	29.61	29.54	29.33	29.50	29.36	29.33
1922 . .	28.92	29.35	29.32	29.38	29.53	29.40	29.67	29.63	29.67	29.50	29.36	29.67	28.92
1923 . .	29.43	29.56	29.15	29.34	29.44	29.32	29.67	29.48	29.74	29.58	29.34	29.29	29.29
1924 . .	29.33	29.62	29.22	29.43	29.26	29.56	29.51	29.45	29.46	29.70	29.20	29.19	29.19
1925 . .	29.19	29.22	29.42	29.57	29.45	29.56	29.64	29.72	29.64	29.10	29.08	29.36	29.08
1926 . .	29.31	29.20	29.19	29.35	29.38	29.59	29.50	29.75	29.79	29.00	29.34	29.50	29.00
1927 . .	29.30	29.39	29.40	29.46	29.53	29.61	29.73	29.70	29.49	29.13	29.02	29.12	29.02
1928 . .	28.90	29.33	29.20	29.36	29.50	29.48	29.67	29.66	29.68	29.55	29.43	29.12	28.90
Mean .	29.18	29.20	29.26	29.41	29.51	29.56	29.60	29.63	29.59	29.42	29.34	29.25	28.95

Mean Temperatures (in Degrees F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	32.9	22.9	37.9	51.1	61.2	67.8	69.5	65.9	62.1	46.4	41.4	34.5	49.5
1890 . .	31.0	32.6	31.9	45.8	56.3	65.2	68.4	67.2	60.4	43.2	36.9	21.8	46.8
1891 . .	26.4	27.6	32.7	47.5	55.6	65.2	66.3	69.0	64.9	48.7	38.1	36.9	48.2
1892 . .	23.6	26.1	31.4	45.2	54.4	69.3	69.3	68.9	59.3	48.6	37.8	26.3	46.7
1893 . .	16.1	22.9	30.4	43.0	55.8	66 9	68.1	69.1	55.8	52.6	38.2	25.5	48.2
1894 . .	26.4	21.5	39.6	46.7	57.3	67.8	72.9	67.9	65.4	51.6	34.8	26.9	48.2
1895 . .	21.5	19.5	31.1	45.6	59.7	69.1	67.5	69.7	64.1	45.6	40.6	30.4	47.0
1896 . .	20.7	25.0	29.2	48.3	61.0	64.0	71.3	68.8	59.5	47.1	42.2	25.6	47.0
1897 . .	24.7	25.4	33.1	47.0	56.7	62.0	71.6	66.8	60.1	49.8	36.2	28.3	46.8
1898 . .	21.8	26.0	39.7	42.4	55.3	66.1	70.9	70.2	63.6	51.1	37.5	25.8	47.5
1899 . .	22.9	21.3	33.6	45.8	57.6	67.8	69.8	68.6	59.4	51.9	37.3	31.0	47.2
1900 . .	24.8	24.6	29.1	45.8	55.1	67.1	71.5	70.6	64.5	55.4	40.8	28.4	48.1
1901 . .	23.6	19.2	32.5	46.4	55.8	66.7	73.3	70.4	62.7	50.7	33.6	26.7	46.8
1902 . .	22.2	25.3	40.5	47.2	56.6	63.1	68.3	66.2	60.9	50.3	42.4	23.7	47.2
1903 . .	24.2	27.2	42.9	47.1	59.8	60.3	69.3	62.4	61.9	51.4	35.1	22.1	47.0
1904 . .	14.3	17.3	30.8	43.2	60.3	65.3	70.4	66.9	60.2	46.0	34.0	19.4	44.0
1905 . .	20.6	17.6	32.8	46.1	57.0	64.3	71.8	66.2	59.8	50.0	36.5	30.1	46.1
1906 . .	30.2	24.1	28.0	45.9	56.9	66.1	71.1	71.2	63.8	51.4	38.7	24.1	47.6
1907 . .	22.1	16.1	35.2	41.7	51.7	63.7	70.4	66.5	62.0	45.7	38.6	31.2	45.4
1908 . .	25.8	20.6	34.8	45.9	59.9	67.2	72.8	67.0	64.0	52.3	38.5	27 6	48.0
1909 . .	25.4	29.3	33.2	45.1	55.7	66.1	68.9	66.8	60.7	48.7	42.0	25.5	47.3
1910 . .	26.2	23.6	40.2	50.4	57.0	63.7	72.2	67.1	61.7	52.3	37.1	21.9	47.8
1911 . .	27.5	22.8	31.7	43.5	62.5	64.4	74.6	68.5	60.4	49.0	37.2	33.5	48.0
1912 . .	14.7	21.4	30.9	46.2	58.8	64.9	71.9	66.4	61.6	53.3	40.5	33.1	46.9
1913 . .	34.2	22.7	38.3	48.0	55.5	66.0	71.6	69.9	60.0	55.5	41.8	32.0	49.6
1914 . .	22.4	17.9	33.7	42.6	58.9	64.6	68.6	69.7	61.0	54.2	37.6	24.7	46.3
1915 . .	27.1	28.9	32.8	51.1	53.8	64.5	69.9	67.0	66.0	52.4	40.8	27.0	48.4
1916 . .	27.7	20.1	26.8	44.6	56.2	61.3	72.5	70.5	61.3	51.7	38.1	26.5	46.4
1917 . .	23.5	19.9	33.4	42.1	49.5	66.3	72.5	72.3	58.4	47.4	34.6	17.1	44.8
1918 . .	13.9	19.6	35.4	46.2	62.2	63.0	71.1	71.6	58.0	53.1	40.0	29.3	46.9
1919 . .	28.7	28.7	38.5	45.7	57.4	68.3	71.8	65.8	61.9	51.6	40.1	23.2	48.5
1920 . .	15.2	21.3	34.3	43.2	54.5	64.7	68.7	71.8	64.1	56.4	36.9	31.0	46.8
1921 . .	26.8	27.5	42.5	52.0	59.0	66.4	74.7	67.2	66.6	50.9	37.9	25.8	49.8
1922 . .	20.1	25.8	35.3	45.8	60.0	67.4	70.8	68.2	64.0	51.7	39.5	25.1	47.8
1923 . .	19.7	17.9	28.6	45.9	56.4	67.9	68.5	67.6	63.9	51.1	39.8	34.8	46.8
1924 . .	25.8	20.7	31.4	44.2	53.2	64.3	71.4	70.3	59.2	51.3	40.5	25.6	46.7
1925 . .	21.1	32.1	39.1	47.5	54.0	69.2	69.1	68.0	61.0	43.5	38.0	29.0	47.6
1926 . .	25.5	22.6	29.4	41.2	55.5	61.6	70.3	69.0	59.8	47.8	39.8	20.1	45.2
1927 . .	22.7	28.7	38.5	45.0	53.9	61.9	70.6	64.9	61.5	54.0	43.9	29.7	47.9
1928 . .	27.3	25.5	33.1	43.3	55.1	63.6	70.3	72.0	59.0	51.8	40.0	32.4	47.8
Mean .	23.8	23.5	34.2	45.8	56.8	65.4	70.6	68.4	61.6	50.4	38.6	27.3	47.2

Range of Temperature (in Degrees F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	48.0	49.0	40.0	46.0	50.0	44.0	31.0	37.0	41.0	43.0	41.0	57.5	92.0
1890 . .	57.0	54.5	69.0	57.5	48.5	47.5	54.0	47.0	52.0	52.0	51.0	48.5	100.5
1891 . .	52.5	60.0	57.5	61.5	62.0	60.0	48.5	47.5	55.5	69.0	60.5	51.5	100.0
1892 . .	66.5	53.5	54.5	58.5	56.0	54.0	52.0	44.0	49.0	54.5	53.0	47.0	104.5
1893 . .	63.0	54.5	48.0	48.5	57.0	52.5	49.5	57.0	51.0	57.0	52.0	64.0	109.0
1894 . .	52.0	66.0	56.0	63.0	56.0	55.5	50.0	54.0	56.0	43.0	55.0	55.0	115.0
1895 . .	50.0	55.0	44.0	56.0	62.5	51.0	54.0	52.0	64.0	51.0	57.0	68.0	105.0
1896 . .	53.0	67.0	52.0	67.5	62.5	51.0	41.0	55.0	57.5	49.0	54.0	62.0	111.0
1897 . .	51.0	59.0	60.5	60.0	48.0	47.5	36.0	43.0	59.5	63.5	58.0	62.5	102.5
1898 . .	65.5	73.0	45.5	54.0	46.0	50.0	56.5	46.5	58.5	59.5	56.0	60.0	115.5
1899 . .	70.5	61.0	42.0	61.0	55.5	51.0	47.0	51.0	51.5	61.5	40.5	59.0	114.5
1900 . .	56.0	64.0	46.0	59.0	67.5	54.0	51.0	53.0	53.5	61.0	55.0	57.5	104.0
1901 . .	55.0	48.5	57.0	58.5	50.5	57.5	52.0	33.5	59.0	51.0	54.0	70.5	111.0
1902 . .	47.5	49.0	48.5	57.5	61.0	49.0	45.0	44.0	51.5	51.5	47.5	64.0	106.0
1903 . .	57.5	68.0	57.0	62.0	68.0	48.5	52.5	42.0	60.5	55.0	68.5	61.5	109.0
1904 . .	66.0	56.0	68.0	50.5	48.0	51.5	48.0	49.5	58.5	59.5	49.0	47.0	120.5
1905 . .	64.0	59.5	76.0	57.0	50.5	54.0	47.0	47.5	53.0	59.0	50.0	51.5	106.0
1906 . .	56.5	57.5	60.5	53.5	58.5	50.5	43.5	43.0	59.5	53.5	43.5	48.5	98.5
1907 . .	78.0	61.5	74.0	49.0	65.0	57.0	46.0	55.0	49.0	52.5	40.5	50.5	119.5
1908 . .	58.5	68.0	62.0	66.0	55.0	55.5	50.5	51.5	55.0	67.5	39.5	63.5	108.0
1909 . .	61.0	57.5	41.0	61.0	49.0	51.5	51.0	56.0	48.0	61.0	53.5	60.0	102.5
1910 . .	65.0	60.5	65.5	56.0	53.0	53.0	48.5	44.5	48.0	65.0	46.0	49.0	106.0
1911 . .	49.0	54.5	56.5	68.0	67.5	45.0	55.0	50.0	55.0	48.5	48.0	52.0	107.0
1912 . .	64.0	66.0	59.5	54.0	55.5	55.0	57.5	50.0	51.0	56.5	48.5	62.0	117.5
1913 . .	48.5	59.5	73.0	62.0	58.5	55.0	59.0	56.0	56.5	54.5	45.0	48.0	104.5
1914 . .	66.0	64.0	60.5	61.5	64.0	51.5	44.0	47.5	72.0	62.5	67.0	77.0	115.0
1915 . .	58.0	49.0	44.5	66.5	46.0	52.0	43.0	46.0	58.5	50.5	49.0	51.0	97.0
1916 . .	62.5	63.5	66.0	45.5	45.5	44.0	47.0	50.5	53.0	58.5	51.5	54.5	111.5
1917 . .	51.0	62.0	60.0	46.0	52.5	38.0	47.0	52.0	54.5	43.0	55.0	63.0	121.0
1918 . .	64.0	73.5	60.5	55.5	50.5	53.0	54.5	56.0	48.5	51.0	47.0	55.0	122.5
1919 . .	62.5	40.5	56.0	56.0	56.0	59.5	49.0	45.0	53.0	54.5	53.0	63.0	110.0
1920 . .	57.5	63.0	71.5	52.5	53.0	43.0	42.5	45.5	53.0	52.0	46.0	54.0	110.0
1921 . .	56.0	59.0	63.5	59.5	56.0	55.5	39.0	46.0	56.0	58.0	44.0	58.0	102.0
1922 . .	53.0	63.0	65.0	57.0	59.5	47.0	45.0	46.5	56.5	68.0	51.5	60.5	107.5
1923 . .	62.5	56.5	64.0	77.5	57.5	55.0	50.5	56.5	56.0	54.5	45.5	50.0	109.0
1924 . .	62.0	47.0	50.0	49.0	41.0	47.5	48.5	55.0	58.0	59.0	70.5	59.0	105.0
1925 . .	54.5	53.0	67.0	56.5	49.5	55.0	44.0	51.5	60.0	53.5	51.0	55.0	110.0
1926 . .	48.0	50.0	57.5	57.5	50.0	51.5	53.0	46.5	49.0	57.0	54.0	53.0	110.0
1927 . .	59.0	48.0	68.0	63.0	44.0	51.5	47.5	38.5	50.0	65.0	50.0	53.0	103.0
1928 . .	58.0	54.0	60.0	62.0	49.5	43.5	46.0	40.0	53.0	66.5	55.0	47.5	96.5
Mean .	58.2	58.2	58.2	57.8	54.6	51.2	48.2	48.3	54.6	56.3	51.4	56.8	108.0

Highest Temperature (in Degrees F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	56.0	47.0	61.0	78.0	88.0	90.0	85.0	82.0	81.0	69.0	61.0	63.0	90.0
1890 . .	61.5	57.5	62.5	79.5	80.0	88.0	94.0	88.5	80.5	78.0	62.5	43.5	94.0
1891 . .	52.0	54.0	56.5	79.5	87.0	94.0	90.0	92.5	91.5	89.0	64.0	60.5	94.0
1892 . .	57.0	46.5	60.5	78.5	84.0	95.0	94.0	94.0	80.0	77.5	67.0	46.0	95.0
1893 . .	50.0	50.0	52.0	67.5	87.0	94.0	90.5	96.0	81.0	80.0	63.0	52.0	96.0
1894 . .	53.0	49.0	73.0	79.0	85.0	93.0	98.0	91.0	91.0	75.0	65.0	51.0	98.0
1895 . .	45.5	45.0	49.0	81.0	92.0	95.0	90.0	90.0	97.0	71.0	72.0	65.0	97.0
1896 . .	41.0	53.0	57.0	88.5	94.5	90.0	91 0	97.0	88.5	72.0	69.0	52.5	97.0
1897 . .	51.0	48.0	59.0	80.5	79.5	85.5	91.0	85.0	91.5	84.0	63.0	59.0	91.5
1898 . .	50.0	54.0	60.0	71.0	78.5	89.5	96.5	91.0	93.0	86.5	62.0	48.0	96.5
1899 . .	49.0	51.0	52.0	82.0	88.5	93.0	90.0	92.0	84.0	82.0	58.0	61.0	93.0
1900 . .	51.5	56.0	49.0	80.8	91.5	94.0	95.5	96.0	89.0	83.0	67.0	58.0	96.0
1901 . .	47.0	44.0	56.5	86.5	82.0	98.5	100.5	86.5	92.0	75.0	60.0	60.0	100.5
1902 . .	47.0	54.0	65.0	83.0	91.0	89.0	90.0	87.0	86.5	74.0	65.0	49.0	91.0
1903 . .	45.5	57.0	76.0	84.0	92.5	86.5	97.0	84.5	91.0	77.5	74.5	52.0	97.0
1904 . .	40.0	48.0	65.0	70.5	85.0	92.5	94.5	89.5	84.5	77.5	56.5	43.5	94.5
1905 . .	51.0	48.5	77.0	79.0	82.5	90.0	93.0	89.0	85.0	80.5	61.0	54.5	93.0
1906 . .	60.0	52 5	53.0	74.5	90.0	87.5	88.5	90.5	91.0	77.5	62.0	45.5	91.0
1907 . .	54.5	43.0	79.5	70.5	90.0	95.0	90.0	96.0	85.0	73.0	60.0	60.5	96.0
1908 . .	53.0	56.0	67.0	84.0	88.5	91.5	96.0	88.5	88.0	90.5	58.0	65.5	96.0
1909 . .	54.0	54.5	54.0	80.0	81.5	91.5	93.0	94.0	83.0	85.0	72.0	51.5	94.0
1910 . .	56.0	53.5	78.0	80.0	84.0	88.0	97.0	85.5	82.0	84.0	61.0	47.0	97.0
1911 . .	50.5	51.5	59.0	86.0	94.5	89.5	104.0	94.5	84.0	72.5	66.5	62.0	104.0
1912 . .	45.0	49.5	60.5	78.0	88.0	91.0	98.5	89.0	86.0	83.0	67.0	65.0	98.5
1913 . .	59.5	55.0	74.0	84.5	89.0	92.0	100.0	97.0	87.5	79.0	68.0	53.0	100.0
1914 . .	52.0	46.5	69.0	83.5	91.0	90.5	89.0	95.0	96.5	84.5	71.5	58.5	96.5
1915 . .	54.0	51.0	57.5	88.0	80.0	89.0	91.0	88.0	93.0	76.0	69.0	53.0	93.0
1916 . .	57.5	47.5	66.0	73.5	81.5	84.0	93.5	95.5	89.5	84.0	64.0	54.5	95.5
1917 . .	47.5	46.0	58.0	71.0	81.0	88.0	98.5	98.0	85.0	70.0	62.0	40.5	98.5
1918 . .	44.0	51.0	69.0	79.5	86.5	93.0	99.5	100.0	84.0	78.5	62.5	52.0	100.0
1919 . .	54.0	49.0	68.0	74.0	89.0	101.0	98.0	88.0	88.0	81.5	70.0	54.0	101.0
1920 . .	41.0	45.0	70.5	74.5	83.5	88.0	87.5	92.0	90.0	81.5	62.0	58.0	92.0
1921 . .	50.0	55.0	79.5	85.0	89.0	96.0	93.5	91.0	92.0	79.5	66.0	57.0	96.0
1922 . .	41.0	49.5	72.0	81.5	87.5	90.0	94.0	90.5	86.5	88.5	66.0	54.0	94.0
1923 . .	50.5	46.0	60.0	86.0	86.5	97.0	94.0	94.0	86.5	81.0	66.5	57.0	97.0
1924 . .	51.0	44.5	58.0	71.0	74.0	87.0	95.5	97.0	90.5	78.5	75.0	58.0	97.0
1925 . .	41.5	57.0	74.0	82.0	80.0	97.0	91.5	90.5	86.0	73.0	62.0	56.5	97.0
1926 . .	48.0	43.0	57.0	75.5	80.0	86.5	100.0	91.5	87.0	81.0	69.0	43.0	100.0
1927 . .	47.0	55.0	74.0	85.0	75.0	89.0	91.0	82.5	84.5	89.0	70.0	61.5	91.0
1928 . .	54.5	50.5	68.0	82.5	80.5	85.0	93.0	92.0	84.0	86.0	73.0	56.0	93.0
Mean .	50.4	50.3	63.9	79.5	85.5	91.1	93.9	91.3	87.4	79.7	65.3	51.5	95.8

Lowest Temperature (in Degrees F.)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	8.0	—2.0	21.0	32.0	38.0	46.0	34.0	45.0	40.0	26.0	20.0	5.5	—2 0
1890 . .	4.5	3.0	—6.5	22.0	31.5	40.5	40.0	41.5	28.5	26.0	11.5	—5.0	—6 5
1891 . .	—0.4	—6.0	—1.0	18.0	25.0	34.0	41.5	45.0	36.0	20.0	3.5	9.0	—6.0
1892 . .	—9.5	—7.0	6.0	20.5	28.0	41.0	42.0	50.0	31.0	23.0	14.0	—1.0	—9.5
1893 . .	—13.0	—4.5	4.0	19.0	30.0	41.5	41.0	39.0	30.0	23.0	11.0	—12.0	—13.0
1894 . .	1.0	—17.0	17.0	16.0	29.0	37.5	48.0	37.0	35.0	32.0	10.0	—4.0	—17.0
1895 . .	—4.5	—10.0	5.0	25.0	29.5	44.0	46.0	38.0	33.0	20.0	15.0	—3.0	—10.0
1896 . .	—12.0	—14.0	5.0	21.0	32.0	39.0	50.0	42.0	31.0	23.0	15.0	—9.5	—14.0
1897 . .	0.0	—11.0	—1.5	20.5	31.5	38.0	55.0	42.0	32.0	20.5	5.0	—3.5	—11.0
1898 . .	—15.5	—19.0	14.5	17.0	32.5	39.5	40.0	44.5	34.5	27.0	6.0	—12.0	—19.0
1899 . .	—21.5	—10.0	10.0	21.0	33.0	42.0	43.0	41.0	32.5	20.5	17.5	2.0	—21.5
1900 . .	—4.5	—8.0	3.0	21.0	24.0	40.0	44.5	43.0	35.5	22.0	12.0	0.5	—8.0
1901 . .	—8.0	—4.5	—0.5	28.0	31.5	41.0	48.5	53.0	33.0	24.0	6.0	—10.5	—10.5
1902 . .	—0.5	5.0	16.5	25.5	30.0	40.0	45.0	43.0	35.0	22.5	17.5	—15.0	—15.0
1903 . .	—12.0	—11.0	19.0	22.0	21.5	38.0	44.5	42.5	30.5	22.5	6.0	—9.5	—12.0
1904 . .	—26.0	—8.0	—3.0	20.0	37.0	44.0	46.5	40.0	26.0	18.0	7.5	—3.5	—26 0
1905 . .	—13.0	—11.0	1.0	22.0	32.0	36.0	46.0	41.5	32.0	21.5	11.0	3.0	—13.0
1906 . .	3.5	—5.0	—7.5	21.0	31.5	37.0	45.0	47.5	31.5	24.0	18.5	—3.0	—7.5
1907 . .	—23.5	—18.5	5.5	20.5	25.0	38.0	44.0	41.0	36.0	20.5	19.5	10.0	—23.5
1908 . .	—5.5	—12.0	5.0	18.0	33.5	36.0	46.0	37.0	33.0	23.0	18.5	2.0	—12.0
1909 . .	—7.0	—3.0	13.0	19.0	32.5	40.0	42.0	38.0	35.0	24.0	18 5	—8.5	—8.5
1910 . .	—9.0	—7.0	12.5	24.0	31.0	35.0	18.5	41.0	34.0	19.0	15.0	—2.0	—9.0
1911 . .	1.5	—3.0	2.5	18.0	27.0	44.5	49.0	44.5	29.0	24.0	18.5	10.0	—3.0
1912 . .	—19.0	—16.5	1.0	24.0	32.5	36.0	41.0	39.0	35.0	26.5	18.5	3.0	—19.0
1913 . .	11.0	—4.5	1.0	22.5	30.5	37.0	41.0	41.0	31.0	24.5	23.0	5.0	—4.5
1914 . .	—14.0	—17.5	8.5	22.0	27.0	39.0	45.0	47.5	24.5	22.0	4.5	—18.5	—18.5
1915 . .	—4.0	2.0	13.0	21.5	34.0	37.0	48.0	42.0	34.5	25.5	20.0	2.0	—4.0
1916 . .	—5.0	—16.0	0.0	28.0	36.0	40.0	46.5	45.5	36.5	25.5	12.5	0.0	—16.0
1917 . .	—3.5	—16.0	—2.0	25.0	28.5	50.0	51.5	46.0	30.5	27.0	7.0	—22.5	—22.5
1918 . .	—20.0	—22.5	8.5	24.0	36.0	40.0	45.0	44.0	34.5	27.5	15.5	—3.0	—22.5
1919 . .	—8.5	8.5	12.0	18.0	33.0	41.5	49.0	43.0	35.0	27.0	17.0	—9.0	—9.0
1920 . .	—16.5	—18.0	—1.0	22.0	30.5	45.0	45.0	46.5	37.0	29.5	16.0	4.0	—18.0
1921 . .	—6.0	—4.0	16.0	25.5	33.0	40 5	54.5	45.0	36.0	21.5	22.0	—1.0	—6.0
1922 . .	—12.0	—13.5	7.0	24.5	28.0	43.0	49.0	40.0	30.0	20.5	14.5	—6.5	—13.5
1923 . .	—12.0	—10.5	—4.0	8.5	29.0	42.0	43.5	37.5	30.5	26.5	21.0	7.0	—12.0
1924 . .	—8.0	—2.5	8.0	22.0	33.0	39.5	47.0	42.0	32.5	19.5	4.5	—1.0	—8 0
1925 . .	—13.0	4.0	7.0	25.5	30.5	42.0	47.5	39.0	26.0	20.5	11.0	1.5	—13.0
1926 . .	0.0	—7.0	—0.5	18.0	30.0	35.0	47.0	45.0	38.0	24.0	15.0	—10.0	—10.0
1927 . .	—12.0	7.0	6.0	22.0	31.0	37.5	43.5	44.0	34.5	24.0	20.0	8.5	—12.0
1928 . .	—3.5	—3.5	8.0	20.5	31.0	41.5	47.0	52.0	31.0	19.5	14 5	8.5	—3.5
Mean—	—7 4	—7.9	5.7	21.6	30.8	40.0	45.5	42.9	32.8	23.4	13.8	—2 3	—12.1

Mean Relative Humidity

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	79.0	90.0	75.0	78.3	73.8	79.1	78.2	80.4	83.3	75.7	75.4	75.2	78.6
1890 . .	68.2	74.8	77.3	64.7	67.1	71.3	70.1	74.9	80.9	68.2	67.8	67.2	71.1
1891 . .	72.2	69.4	63.7	60.1	59.3	65.3	66.1	70.3	72.1	65.5	68.7	68.7	66.8
1892 . .	73.7	72.8	64.1	54.5	60.3	68.9	65.6	74.9	70.7	65.5	71.0	70.3	67.7
1893 . .	80.2	74.7	71.4	64.8	66.0	71.1	64.8	70.7	72.8	67.0	68.8	80.9	71.1
1894 . .	78.8	77.5	67.5	60.5	65.8	68.1	68.2	69.9	74.4	82.7	70.8	79.0	71.9
1895 . .	82.5	83.9	80.6	68.1	65.0	68.5	72.7	72.7	73.7	69.2	80.5	75.4	74.4
1896 . .	73.3	87.5	85.3	62.0	62.5	67.3	73.1	79.9	84.0	85.0	82.3	79.8	76.9
1897 . .	77.1	75.7	78.9	68.2	71.5	73.3	80.1	79.6	76.6	68.7	83.2	83.9	76.4
1898 . .	85.2	83.1	72.6	72.1	78.4	77.1	79.3	82.1	80.0	83.6	83.4	80.2	79.8
1899 . .	77.7	82.5	79.1	69.2	70.3	74.0	75.2	74.1	74.0	75.9	76.2	79.4	75.6
1900 . .	75.1	77.4	67.8	64.7	65.5	69.5	71.1	75.9	73.1	77.0	75.9	74.9	72.3
1901 . .	74.3	68.5	70.8	68.1	68.1	65.5	72.3	76.3	76.8	70.5	71.1	69.8	71.0
1902 . .	66.2	66.8	72.3	67.1	63.4	70.8	77.2	76.3	79.1	70.9	75.6	72.5	71.6
1903 . .	72.0	77.7	76.4	64.7	61.3	81.1	71.4	78.2	75.0	74.5	73.5	76.5	73.5
1904 . .	85.5	77.7	74.4	70.8	69.7	77.0	77.7	80.5	81.8	74.0	77.5	77.8	77.0
1905 . .	77.2	75.1	76.7	66.7	68.2	78.8	79.1	82.5	83.2	75.9	73.5	80.6	76.5
1906 . .	74.8	77.4	73.9	70.3	70.9	79.1	82.4	82.9	80.1	84.1	72.2	77.0	77.1
1907 . .	76.1	80.2	73.4	74.1	75.3	76.9	76.4	74.9	83.0	77.7	85.9	80.4	77.9
1908 . .	73.8	84.8	77.9	64.3	74.8	66.2	76.6	79.0	79.1	79.0	79.6	75.1	75.8
1909 . .	78.5	78.9	81.3	76.3	71.2	73.6	71.8	78.1	83.1	76.1	77.2	75.2	76.8
1910 . .	80.9	81.3	72.8	69.1	71.6	75.4	70.3	76.3	82.7	75.0	78.7	78.4	76.0
1911 . .	78.8	77.6	73.2	65.2	72.2	74.5	70.7	77.5	82.4	79.0	73.5	77.3	75.2
1912 . .	81.3	78.4	80.3	77.2	78.5	70.0	71.5	78.3	84.0	74.9	77.2	75.4	77.3
1913 . .	79.0	74.5	79.3	74.4	73.0	68.4	70.5	74.2	80.2	79.2	74.0	81.2	75.7
1914 . .	81.4	72.0	76.4	75.5	74.5	76.1	80.7	80.3	74.3	75.3	69.6	73.2	75.8
1915 . .	80.8	78.9	65.4	67.8	66.8	71.4	82.1	85.0	80.8	81.6	74.7	71.6	75.6
1916 . .	81.4	79.9	86.8	81.2	71.9	75.7	81.8	80.7	81.3	78.4	82.3	81.7	80.3
1917 . .	82.4	82.7	77.8	74.6	70.4	78.3	79.4	80.0	83.5	79.6	71.1	76.9	78.1
1918 . .	77.1	76.0	71.9	69.2	72.2	72.9	74.5	75.5	81.3	80.5	81.3	84.5	76.4
1919 . .	79.6	78.6	70.6	68.1	70.8	73.9	77.1	77.3	84.2	83.8	79.1	87.1	77.5
1920 . .	87.7	82.9	78.2	72.5	71.1	77.5	77.6	84.3	83.9	86.7	73.9	73.7	79.2
1921 . .	72.2	68.4	72.4	76.9	75.2	70.9	83.6	77.8	79.5	76.3	80.3	78.5	76.0
1922 . .	78.5	80.5	77.6	73.2	72.2	85.9	80.6	81.6	83.4	75.5	73.4	81.8	78.7
1923 . .	80.1	73.2	76.3	65.3	66.9	70.2	75.2	77.0	81.5	81.5	81.5	77.4	75.5
1924 . .	79.9	77.5	70.2	66.9	70.3	73.8	73.5	76.2	80.1	72.9	70.9	74.6	73.9
1925 . .	81.5	82.8	78.4	78.2	79.3	78.1	81.6	84.3	83.9	80.0	77.8	79.9	80.5
1926 . .	79.4	78.1	75.4	75.0	81.6	78.9	74.1	82.7	83.5	81.2	80.8	78.9	79.4
1927 . .	85.3	85.3	75.2	68.7	83.9	80.2	88.8	87.3	89.0	85.3	84.3	81.3	82.9
1928 . .	78.9	77.2	80.2	76.8	77.1	82.6	80.6	86.3	85.2	79.2	78.1	77.0	79.9
Mean	78.2	77.9	75.0	69.6	70.7	73.9	75.6	78.4	80.0	76.9	76.3	77.2	75.8

Mean Per Cent of Cloudiness

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	55	40	63	55	42	53	54	43	65	60	68	61	55
1890 . .	52	66	66	50	59	50	56	57	59	64	47	53	57
1891 . .	61	59	55	49	54	47	54	58	50	54	50	51	53
1892 . .	63	55	45	42	66	50	35	53	29	46	58	45	49
1893 . .	52	57	46	55	55	58	44	45	46	40	49	54	50
1894 . .	53	53	55	53	52	54	50	44	53	44	50	44	50
1895 . .	51	39	55	54	46	48	58	44	42	42	61	45	49
1896 . .	43	63	54	39	40	47	50	40	52	63	59	42	49
1897 . .	46	51	56	46	47	47	64	42	39	39	71	68	51
1898 . .	66	64	53	68	65	57	53	60	48	62	60	66	60
1899 . .	53	58	66	42	54	54	50	57	47	60	53	52	54
1900 . .	52	62	47	46	54	49	48	49	54	64	72	62	55
1901 . .	58	45	68	75	70	48	63	67	51	48	65	65	60
1902 . .	60	63	66	68	58	62	66	50	57	51	62	60	60
1903 . .	61	53	63	50	36	71	52	63	42	58	41	49	53
1904 . .	55	42	57	52	45	59	55	47	54	42	43	57	51
1905 . .	58	31	46	43	56	61	55	56	48	36	42	56	49
1906 . .	51	44	49	49	47	54	53	50	32	52	53	66	50
1907 . .	58	41	44	33	68	50	42	36	64	30	48	51	49
1908 . .	37	42	48	42	50	28	47	45	27	37	46	49	41
1909 . .	61	60	49	52	56	44	33	35	55	49	56	45	50
1910 . .	60	57	49	56	66	59	34	47	55	44	68	55	54
1911 . .	62	55	49	42	55	54	42	61	53	59	60	63	55
1912 . .	55	36	53	64	64	43	46	50	60	40	51	58	52
1913 . .	63	42	62	55	53	35	39	41	47	63	53	45	50
1914 . .	63	42	53	56	42	48	69	61	27	44	41	54	50
1915 . .	51	51	27	46	46	41	49	63	53	44	44	55	43
1916 . .	44	59	43	65	53	62	57	54	45	43	51	53	53
1917 . .	64	45	50	46	50	49	48	50	39	55	34	46	48
1918 . .	44	45	36	52	51	45	44	37	56	52	49	55	47
1919 . .	52	38	51	50	50	43	45	44	54	57	53	39	48
1920 . .	49	52	41	51	39	51	50	55	52	48	65	57	51
1921 . .	42	63	59	62	36	43	66	40	39	42	66	45	50
1922 . .	38	54	49	40	34	56	48	58	41	32	40	54	45
1923 . .	58	43	40	38	30	38	42	27	50	44	48	52	45
1924 . .	49	32	44	47	54	40	31	33	47	18	44	57	41
1925 . .	51	45	48	34	54	53	51	37	57	53	47	56	49
1926 . .	55	49	43	49	49	43	52	60	59	54	49	52	51
1927 . .	55	66	46	34	60	48	60	55	48	39	72	50	53
1928 . .	54	49	52	50	54	63	50	60	52	34	53	47	51
Mean .	53.8	50.5	50.8	49.2	51.5	50.1	50.1	49.4	48.7	47.6	53.5	53.4	50.8

Hours of Bright Sunshine by Sun Thermometer

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Possible hours	294	296	371	402	453	457	462	429	373	341	293	283	4,454
1889 . .	134	183	138	191	270	277	182	194	120	129	84	108	2,010
1890 . .	112	131	160	245	225	264	289	199	166	129	143	131	2,194
1891 . .	126	124	195	240	226	248	222	204	224	150	141	143	2,245
1892 . .	128	138	196	244	183	218	287	201	234	178	101	144	2,261
1893 . .	130	111	172	166	188	209	259	225	185	182	133	112	2,072
1894 . .	120	121	150	174	208	180	237	237	176	160	128	159	2,051
1895 . .	153	187	172	188	243	246	192	251	254	197	111	169	2,363
1896 . .	157	168	210	258	297	263	260	254	189	115	105	172	2,448
1897 . .	144	154	188	239	236	248	214	274	221	209	90	108	2,325
1898 . .	132	138	200	168	200	270	236	201	218	157	126	113	2,159
1899 . .	151	147	134	280	221	235	259	206	200	140	130	142	2,245
1900 . .	167	120	216	227	235	259	260	226	177	136	86	108	2,216
1901 . .	117	172	93	103	159	254	208	160	215	178	100	107	1,866
1902 . .	120	138	143	139	210	179	185	209	119	164	109	119	1,864
1903 . .	114	145	138	199	311	102	247	169	236	154	182	129	2,126
1904 . .	144	173	172	182	256	256	274	292	204	183	148	115	2,401
1905 . .	119	178	216	247	286	247	263	242	186	209	156	128	2,477
1906 . .	128	183	225	269	288	316	278	266	254	189	155	111	2,660
1907 . .	130	200	245	268	209	217	297	217	110	177	125	122	2,317
1908 . .	154	200	220	277	282	362	308	268	242	186	111	133	2,743
1909 . .	127	157	232	220	263	300	290	241	192	194	146	148	2,510
1910 . .	119	180	275	286	287	279	371	229	245	229	137	156	2,793
1911 . .	145	132	236	296	320	280	297	227	195	124	74	105	2,431
1912 . .	149	180	224	198	214	314	260	238	156	163	146	148	2,390
1913 . .	179	205	182	211	221	312	324	282	182	91	113	121	2,423
1914 . .	95	178	170	194	321	283	241	209	246	164	113	160	2,377
1915 . .	144	115	290	223	273	269	191	152	181	162	118	106	2,224
1916 . .	140	140	217	123	191	156	184	259	255	228	141	127	2,036
1917 .	131	180	232	294	317	250	285	287	240	142	170	156	2,684
1918 .	173	154	252	235	258	265	286	276	187	180	108	158	2,532
1919 . .	166	216	232	249	282	326	323	259	179	148	123	120	2,569
1920 .	214	214	242	218	281	241	322	262	243	196	86	143	2,662
1921 . .	167	177	297	215	305	316	285	317	251	206	97	152	2,695
1922 . .	190	147	178	228	334	266	307	256	231	190	109	86	2,522
1923 . .	76	133	192	250	325	360	358	308	224	232	153	162	2,773
1924 . .	175	221	292	288	265	313	336	280	188	225	135	120	2,838
1925 . .	124	141	191	240	242	297	288	280	182	128	127	121	2,361
1926 . .	146	148	219	195	213	216	302	205	159	136	89	130	2,188
1927 . .	123	110	188	208	137	201	206	197	233	215	66	160	1,984
1928 . .	132	176	214	236	227	171	249	203	170	167	121	135	2,201
Mean .	140	160	201	221	250	257	267	237	203	171	121	131	2,356
Mean per cent .	47.6	54.1	54.2	55.0	55.2	56.2	57.8	55.2	54.4	50.1	41.3	46.3	52.9

Precipitation (in Inches)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	3.29	1.45	1.46	2.42	4.71	5.01	10.52	2.72	3.17	4.58	6.04	3.57	48.94
1890 . .	2.61	4.20	5.37	1.73	5.39	1.53	5.63	4.88	5.85	7.13	1.32	2.86	48.50
1891 . .	6.75	4.23	2.99	2.66	1.97	4.75	5.28	4.18	2.66	2.94	2.99	5.40	46.80
1892 . .	5.85	1.90	2.40	.76	6.28	3.46	4.41	6.47	2.16	.66	4.98	1.01	40.34
1893 . .	3.33	5.75	3.66	4.41	5.02	3.32	2.59	3.49	2.82	4.88	2.81	4.86	46.94
1894 . .	2.16	1.74	1.77	1.83	4.00	3.13	1.55	.31	4.63	4.85	3.14	3.53	32.64
1895 . .	3.87	1.05	2.71	5.56	2.07	2.76	3.87	3.46	5.04	4.77	5.36	3.94	44.46
1896 . .	1.07	4.67	6.11	1.32	2.58	2.57	4.96	3.84	5.41	3.23	3.03	.87	39.66
1897 . .	3.00	2.52	3.53	2.42	4.38	6.65	14.51	4.29	1.94	.73	5.85	7.23	57.05
1898 . .	7.15	3.80	1.63	3.73	5.61	3.69	4.09	6.85	3.65	6.27	5.48	2.30	54.25
1899 . .	2.80	3.56	7.13	1.79	1.28	4.13	4.89	2.00	7.90	1.84	2.17	2.00	41.49
1900 . .	4.08	8.12	5.76	1.85	3.78	3.65	4.67	4.11	3.67	3.72	5.87	2.40	51.68
1901 . .	1.81	.62	5.66	5.95	6.91	.87	3.86	6.14	4.17	3.88	2.08	7.77	49.72
1902 . .	1.72	3.54	5.29	3.31	2.32	4.54	4.66	4.65	5.83	5.59	1.27	4.27	46.99
1903 . .	3.28	4.27	6.40	2.30	.48	7.79	4.64	4.92	1.66	2.72	2.04	3.95	44.45
1904 . .	4.74	2.45	4.48	5.73	4.55	5.35	2.62	4.09	5.45	1.74	1.35	2.75	45.30
1905 . .	3.90	1.70	3.66	2.56	1.28	2.86	2.63	6.47	6.26	2.27	2.06	3.15	38.80
1906 . .	2.18	2.73	4.90	3.25	4.95	2.82	3.45	6.42	2.59	5.69	1.98	4.49	45.45
1907 . .	2.73	1.92	1.82	1.98	4.02	2.36	3.87	1.44	8.74	5.00	4.50	3.89	42.27
1908 . .	2.25	3.53	2.86	1.97	4.35	.76	3.28	4.27	1.73	1.57	1.06	3.05	30.68
1909 . .	3.56	5.16	3.01	5.53	3.36	2.24	2.21	3.79	4.99	1.23	1.06	2.95	39.12
1910 . .	6.14	5.08	1.37	3.07	2.67	2.65	1.90	4.03	2.86	.93	3.69	1.72	36.11
1911 . .	2.36	2.18	3.80	1.87	1.37	2.02	4.21	5.92	3.41	8.81	3.84	4.42	44.21
1912 . .	2.18	3.16	5.70	3.92	4.34	.77	2.61	3.22	2.52	2.07	4.03	4.04	38.56
1913 . .	3.98	2.94	6.38	3.30	4.94	.90	1.59	2.26	2.56	5.16	2.11	3.38	39.50
1914 . .	3.72	3.36	5.52	6.59	3.56	2.32	3.53	5.11	.52	2.09	2.62	2.89	41.83
1915 . .	6.52	7.02	.12	3.99	1.20	3.00	9.13	8.28	1.37	2.89	2.20	5.86	51.58
1916 . .	2.56	5.27	3.97	3.69	3.21	5.34	6.85	2.49	5.08	1.01	3.29	2.85	45.61
1917 . .	3.64	1.98	4.08	1.83	4.13	5.27	3.36	7.06	2.42	6.60	.63	2.56	43.56
1918 . .	4.11	2.99	2.91	2.78	2.47	4.01	1.84	2.22	7.00	1.32	2.87	2.95	37.47
1919 . .	2.02	2.80	4.22	2.37	6.20	1.09	4.17	4.81	4.25	1.81	6.20	1.48	41.42
1920 .	2.74	4.45	3.63	4.71	3.65	6.26	2.06	3.62	6.74	1.54	5.62	6.02	51.04
1921 . .	2.00	2.38	3.57	6.47	4.56	3.87	6.00	2.35	1.84	1.08	6.20	1.90	42.22
1922 . .	1.56	3.02	5.34	2.81	5.47	9.68	4.28	4.25	2.27	2.55	1.56	3.15	45.94
1923 . .	6.02	1.81	1.98	3.19	3.26	2.21	1.77	2.55	1.89	5.50	5.05	4.23	39.49
1924 . .	3.85	2.56	1.05	4.54	2.21	1.28	1.75	3.11	5.87	.01	2.57	2.16	30.96
1925 . .	3.42	3.64	4.12	3.10	2.55	4.28	6.97	1.93	3.09	4.74	3.23	3.56	44.63
1926 . .	3.23	5.01	3.95	3.62	1.19	2.03	3.24	3.97	1.50	5.02	5.38	2.78	40.92
1927 . .	2.50	2.62	1.96	1.60	4.83	3.37	3.40	5.01	2.79	4.59	8.64	5.65	46.96
1928 . .	2.19	2.90	1.17	4.16	3.25	6.97	6.23	8.40	3.07	.87	1.88	.97	42.06
Mean .	3.42	3.35	3.68	3.27	3.63	3.54	4.33	4.24	3.79	3.35	3.45	3.47	43.49

Wind Movement (in Miles)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1889 . .	5,101	4,828	7,068	5,648	4,056	4,056	4,032	2,811	4,310	4,762	2,589	4,445	53,706
1890 . .	4,914	4,616	5,395	5,032	5,284	3,776	3,976	4,116	3,507	4,143	4,228	5,673	54,648
1891 . .	4,954	4,759	6,261	5,484	4,610	3,713	3,907	3,324	3,201	4,319	5,215	5,465	55,212
1892 . .	5,059	3,438	7,046	5,370	5,056	4,500	3,365	3,390	3,672	4,071	5,231	4,522	54,720
1893 . .	4,056	5,242	5,757	5,384	4,833	3,572	3,640	4,126	3,508	4,198	4,179	3,916	52,411
1894 . .	4,193	4,865	4,406	4,105	2,180	1,838	1,109	1,920	1,414	2,540	4,179	3,508	36,257
1895 . .	2,896	3,920	4,360	4,098	4,071	3,050	2,934	3,397	3,444	4,029	4,156	5,506	46,861
1896 . .	4,943	6,445	8,182	4,674	4,838	3,926	4,048	2,968	4,686	4,544	4,654	5,290	59,198
1897 . .	5,501	4,493	5,363	5,523	5,603	4,208	4,007	3,452	3,506	3,938	4,558	4,068	54,220
1898 . .	3,494	3,699	3,864	5,477	4,769	4,162	3,377	3,111	2,787	3,999	4,856	4,830	48,425
1899 . .	4,926	4,427	5,275	3,984	4,219	3,814	3,891	2,522	3,967	2,582	3,361	4,142	47,110
1900 . .	4,904	5,016	5,602	5,039	4,381	4,101	3,701	2,322	3,042	3,315	4,877	4,203	50,503
1901 . .	5,224	5,484	5,482	6,211	4,525	3,647	2,763	2,144	2,358	3,652	4,583	4,280	50,353
1902 . .	4,078	5,199	6,601	4,642	4,328	4,102	2,929	2,386	2,680	4,398	3,077	4,018	48,438
1903 . .	4,254	4,529	4,169	5,125	3,908	3,130	3 087	2,105	2,890	4,703	3,362	4,994	46,256
1904 . .	4,112	4,910	4,444	4,902	3,830	3,127	3,268	3,232	3,602	4,160	3,470	3,940	46,994
1905 . .	5,180	4,503	3,006	4,855	5,004	3,108	3,464	3,030	2,527	3,397	4,317	4,051	46,442
1906 . .	5,706	4,565	5,686	4,777	3,766	1,409	3,773	3,412	4,249	4,398	5,978	5,554	53,273
1907 . .	4,987	5,272	5,718	7,096	5,946	4,223	4,114	3,928	3,582	5,111	4,773	5,266	60,016
1908 . .	7,770	5,511	5,759	8,208	5,818	4,571	3,815	3,802	3,757	3,643	5,485	5,432	63,571
1909 . .	5,991	5,585	7,034	6,679	5,371	4,225	5,097	3,485	4,008	4,400	5,793	5,845	63,513
1910 . .	5,786	5,834	5,579	5,533	5,289	3,685	3,812	4,271	3,336	5,467	5,215	5,435	59,242
1911 . .	6,085	5,515	7,485	5,738	4,939	3,546	3,878	3,029	3,809	3,451	5,950	4,857	58,282
1912 . .	4,872	4,798	5,291	6,094	5,332	4,533	3,992	3,698	2,980	3,953	5,037	5,337	55,897
1913 . .	5,359	5,194	6,413	5,659	3,672	3,746	4,315	3,441	3,220	4,698	5,003	4,400	55,120
1914 . .	5,442	5,855	5,663	6,194	4,491	4,468	3,555	3,198	2,992	3,612	5,280	4,705	55,455
1915 . .	3,986	4,341	6,864	5,195	4,087	2,439	2,908	3,199	3,332	3,786	5,402	4,947	50,486
1916 . .	6,341	5,504	5,556	4,836	4,893	3,226	3,126	3,120	3,717	4,176	3,929	4,026	52,450
1917 . .	4,701	4,485	5,804	3,853	4,610	2,081	2,133	2,548	1,702	4,118	3,721	4,897	44,653
1918 . .	5,491	5,632	5,791	4,544	4,906	3,858	3,093	2,583	3,271	4,297	3,730	3,239	50,435
1919 . .	4,554	5,031	7,361	5,374	4,290	3,456	3,719	3,210	3,244	2,914	5,207	4,022	52,335
1920 . .	4,734	4,791	6,263	6,158	3,703	3,055	3,817	2,802	3,411	3,188	4,268	5,280	51,470
1921 . .	5,616	3,835	6,486	4,867	4,400	3,832	2,421	3,709	3,568	4,494	4,441	4,704	52,373
1922 . .	5,353	3,909	4,883	5,661	4,516	3,527	2,847	3,007	2,775	4,670	4,566	4,256	49,970
1923 . .	4,392	4,013	6,058	6,093	4,519	3,314	2,852	3,312	2,704	3,800	3,379	4,428	48,864
1924 . .	6,163	3,971	6,600	5,839	5,135	3,190	3,412	3,282	3,274	3,643	4,779	4,597	53,855
1925 . .	5,688	4,281	4,982	5,268	4,005	4,072	3,292	2,270	3,355	4,231	5,173	6,694	53,311
1926 . .	4,993	5,273	4,884	6,063	5,150	3,951	2,964	2,375	2,416	3,518	4,608	3,645	49,840
1927 . .	4,618	4,366	4,483	5,374	5,535	3,475	3,426	2,818	2,515	4,082	5,213	5,546	49,451
1928 . .	6,419	5,377	6,613	6,770	3,716	3,632	3,545	3,090	3,744	4,512	4,736	5,061	57,215
Mean .	5,068	4,833	5,738	5,436	4,540	3,584	3,435	3,099	3,252	4,023	4,564	4,726	52,321

Maximum Velocity of Wind (in Miles Per Hour)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Annual
1906 . .	26	29	26	30	26	18	26	21	21	35	28	30	35
1907 . .	30	33	36	30	21	26	30	21	26	30	30	35	36
1908 . .	35	35	28	33	26	21	39	19	23	30	30	26	39
1909 . .	30	30	37	36	27	26	24	19	26	23	30	28	37
1910 . .	33	28	30	27	26	24	21	16	16	30	26	35	35
1911 . .	41	26	36	37	30	21	26	21	21	21	30	33	41
1912 . .	30	42	19	28	35	21	19	26	18	23	33	30	42
1913 . .	39	30	39	26	26	21	23	21	21	30	33	28	39
1914 . .	32	33	37	37	26	21	26	26	26	21	33	30	37
1915 . .	26	23	30	28	23	21	39	35	39	26	39	39	39
1916 . .	30	30	26	39	30	21	18	16	21	35	33	27	39
1917 . .	30	26	28	33	23	23	21	14	15	30	21	21	33
1918 . .	27	37	32	25	21	21	21	21	21	26	21	21	37
1919 . .	30	26	26	27	23	16	19	19	18	21	26	30	30
1920 . .	26	26	30	29	26	21	23	30	30	33	28	27	33
1921 . .	26	23	24	21	21	21	15	18	26	26	30	30	30
1922 . .	35	26	28	30	23	35	26	18	21	23	27	30	35
1923 . .	24	28	30	30	21	23	16	21	16	26	19	26	30
1924 . .	32	26	30	30	26	19	35	21	26	19	26	26	35
1925 . .	23	30	21	24	21	26	19	16	18	35	30	30	35
1926 . .	35	26	26	26	23	21	26	18	16	27	30	21	35
1927 . .	26	35	30	26	21	26	23	19	21	27	28	26	35
1928 . .	35	21	26	28	23	16	23	26	24	27	39	41	41
Maximum	40	42	39	39	35	35	39	35	39	35	40	41	42

Snow, Frost and Weather

Year	Last Snow	First Snow	Total Snowfall (Inches)	Last Frost	First Frost	Number of Days of Precipitation	Number of Clear Days	Number of Fair Days	Number of Cloudy Days
1889 . .	April 2	Oct. 13	26.0	May 26	Sept. 21	119	94	110	161
1890 . .	April 8	Oct. 19	43.5	May 12	Sept. 25	141	137	105	123
1891 . .	May 5	Nov. 26	54.2	May 19	Oct. 12	112	145	103	117
1892 . .	April 10	Nov. 5	42.5	May 10	Sept. 30	108	123	109	134
1893 . .	April 21	Nov. 4	74.3	May 8	Sept. 3	143	101	96	168
1894 . .	April 12	Nov. 5	71.5	May 22	Aug. 22	125	107	83	175
1895 . .	April 3	Oct. 20	61.0	May 17	Aug. 22	119	118	110	137
1896 . .	April 7	Nov. 14	44.0	May 1	Sept. 24	108	132	192	132
1897 . .	April 27	Nov. 12	52.8	May 8	Sept. 22	127	108	109	148
1898 . .	April 6	Nov. 24	69.5	April 27	Sept. 21	125	78	138	149
1899 . .	April 16	Oct. 12	52.0	May 4	Sept. 14	110	91	139	135
1900 . .	April 9	Nov. 9	37.0	May 29	Sept. 15	131	83	144	138
1901 . .	April 3	Nov. 11	52.3	May 6	Sept. 26	135	81	105	179
1902 . .	April 2	Oct. 29	57.0	May 14	Sept. 6	144	73	113	179
1903 . .	April 4	Oct. 26	33.5	May 2	Sept. 25	116	119	98	148
1904 . .	April 20	Oct. 12	59.5	April 23	Sept. 22	126	142	96	128
1905 . .	May 1	Nov. 9	40.0	May 24	Sept. 12	122	130	128	107
1906 . .	April 23	Nov. 11	56.2	May 20	Sept 25	121	130	140	95
1907 . .	May 11	Nov. 23	54.5	May 22	Sept. 27	122	95	155	115
1908 . .	April 20	Nov. 5	38.5	June 3	Sept. 16	109	143	130	93
1909 . .	April 9	Nov. 5	31.0	May 12	Oct. 13	128	112	151	102
1910 . .	Mar. 14	Nov. 8	44.5	May 6	Sept. 23	117	142	152	71
1911 . .	April 19	Nov. 14	35.0	May 5	Sept. 14	120	106	131	128
1912 . .	April 9	Nov. 3	33.8	May 1	Aug. 31	117	71	182	113
1913 . .	April 9	Oct. 31	26.5	May 15	Sept. 10	135	105	144	116
1914 . .	April 16	Oct. 27	56.7	May 16	Sept. 28	118	100	139	126
1915 . .	April 3	Nov. 17	40.8	May 20	Sept. 23	122	82	156	127
1916 . .	April 14	Nov. 15	59.5	May 19	Sept. 17	126	121	129	136
1917 . .	May 5	Nov. 24	58.0	May 18	Sept. 11	117	129	137	99
1918 . .	April 13	Nov. 4	50.7	April 26	Sept. 11	123	106	151	108
1919 . .	April 25	Nov. 5	24.5	May 1	Sept. 18	132	130	131	104
1920 . .	April 8	Nov. 12	78.0	May 5	Oct. 7	135	118	156	92
1921 . .	April 18	Nov. 7	37.5	May 12	Oct. 9	131	126	141	98
1922 . .	April 23	Nov. 24	58.7	May 12	Sept. 19	120	117	127	121
1923 . .	April 15	Nov. 8	63.7	May 24	Sept. 15	125	141	131	93
1924 . .	April 8	Nov. 9	45.0	May 2	Sept. 24	96	141	145	80
1925 . .	April 13	Oct. 10	34.5	May 26	Sept. 23	130	98	141	126
1926 . .	April 7	Oct. 18	76.0	May 6	Oct. 9	117	83	142	140
1927 . .	April 5	Nov. 10	31.5	May 3	Oct. 11	127	59	158	148
1928 . .	April 23	Nov. 8	30.0	May 14	Sept. 25	122	93	116	157

Summary for the Forty Years 1889-1928, Inclusive

Barometer (Pressure in Inches)

[Readings reduced to sea level.]

Maximum, Feb. 1, 1920, 10 a.m.	31.050
Minimum, Mar. 1, 1914, 8 p.m.	28.470
Mean	30.016
Total range	2.580
Greatest annual range, 1913	2.330
Least annual range, 1923	1.550
Mean annual range	1.860
Greatest monthly range, January, 1913	2.180
Least monthly range, August, 1894	.440
Mean monthly range	1.087

Air Temperature (in Degrees F.)

Highest, July 4, 1911, 3.30 p.m.	104.0
Lowest, Jan. 5, 1904, 7.30 a.m.	-26.0
Mean	47.2
Total range	130.0
Greatest annual range, 1918	122.5
Least annual range, 1889	92.0
Mean annual range	108.0
Greatest monthly range, January, 1907	78.0
Least monthly range, July, 1889	30.0
Mean monthly range	54.5
Greatest daily range, Dec. 10, 1902	54.0
Least daily range, June 2, 1907	2.0

Humidity

Mean dew point	37.8
Mean relative humidity	75.8

Precipitation (in Inches)

Total rain or melted snow	1,737.43
Total snowfall	1,935.40
Greatest annual precipitation, 1897	57.05
Least annual precipitation, 1908	30.68
Mean annual precipitation	43.44
Greatest monthly precipitation, July, 1897	14.51
Least monthly precipitation, October, 1924	.01
Mean monthly precipitation	3.63
Greatest annual snowfall, 1920	78.00
Least annual snowfall, 1919	24.50

Wind (in Miles)

Total movement	2,092,831
Greatest annual movement, 1908	63,571
Least annual movement, 1894	36,257
Mean annual movement	52,321

Greatest monthly movement, April, 1908	8,208
Least monthly movement, July, 1894	1,109
Mean monthly movement	4,358
Greatest daily movement, April 8, 1909	705
Least daily movement, Sept. 29, 1894; Mar. 7, 1890; Jan. 6, 1904; Dec. 4, 1916; Oct. 6, 1920	0
Mean daily movement	143
Maximum velocity for 5 minutes, Feb. 22, 1912, 10 a.m.	42

Weather

Mean cloudiness observed, per cent	50.8
Total number of hours bright sunshine	94,236
Per cent of possible hours bright sunshine	53
Number of clear days	4,399
Number of fair days	5,165
Number of cloudy days	5,152

Publication of this Document Approved by Commission on Administration and Finance

2m-4-'31. No. 2143

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 271 FEBRUARY, 1931

Annual Report

For the Fiscal Year Ending Nov. 30, 1930

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

Requests for Bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION,
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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* In Charge † At East Wareham ‡ At Waltham

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1930

INTRODUCTION

F. J. Sievers, Director

During the past year there have been a few very significant changes in the organization of the Experiment Station and also in the type of service rendered.

What was formerly known as the Market Garden Field Station, located at Waltham, was organized primarily to support a type of research and demonstration of special value to the trucking industry, already well established in the eastern part of the State and particularly in the vicinity of Boston. Consistent with this service the work was directed by the department of vegetable gardening of the Agricultural College. In the beginning its services were largely of an extension and demonstrational nature with very little emphasis on investigation or research. With the demands for more specific fundamental information, research men in plant pathology, entomology, genetics, and floriculture were soon added to the staff with the result that the original system of administration was found not only cumbersome but no longer adequate. To correct this situation and to bring this unit of the Institution into closer and more logical relationship with the central administration, the Board of Trustees, at its June meeting, decided to change the name to the Waltham Field Station and place it under the direction of the Experiment Station at Amherst with R. M. Koon, Research Professor of Vegetable Gardening, directly in charge. This branch Station now holds the same relationship to the main Experiment Station as does the Cranberry Station at East Wareham, both of which are now organized and conducted to give major consideration to research. Conditions under the reorganization should be very nearly ideal because an opportunity is thereby afforded for four departments in the Institution, viz., botany, entomology, floriculture, and olericulture, to plan and direct certain investigations at the Field Station in Waltham through representatives of the respective departments who are in residence there.

The demands for increased service through the Field Station have been pressing for several years, and at the last legislative session these took a very definite form in the introduction and passage of a special bill providing for a liberal increase in equipment and financial support for investigations in floriculture. This new work is already well under way and it is hoped that the results will be of a nature to justify the faith placed in the Experiment Station service by those who were responsible in urging the necessary legislation.

At the Cranberry Station it has been possible to give special and increased consideration to matters influencing quality of product because of very close and satisfactory cooperation with Federal agencies. There

are evidences that here, too, as at the Waltham Field Station, there is a gradual trend toward research from work of a largely demonstrational nature.

The added facilities provided with the completion of the well-equipped horticultural manufactures building on the College campus makes possible a high quality of research work in this field. As a result the program of investigation is being gradually enlarged to include products not heretofore studied.

There is also in evidence the development of an interest on the part of commercial agencies to provide the Experiment Station with financial support for research in specific fields. Several cooperative projects supported by funds from this source are already under way. This development up to the present has proved very satisfactory both from the standpoint of the donors and of the public whom we are primarily organized to serve, and it is hoped to encourage these relationships.

The reorganization of the Graduate School in July, 1930, whereby its administration was transferred to the Director of the Experiment Station, should prove of advantage to both of these units which are organized so directly around a research program. Many phases of regularly approved Experiment Station projects lend themselves very effectively to graduate study, and already several students are working on such assignments for credit toward an advanced degree.

With the strengthening of the Extension Service program, many of the activities previously considered essential in the Experiment Station are gradually requiring less emphasis. This is evidenced especially in field work as conducted by the departments of agronomy and pomology. Many so-called investigations, which in reality are demonstrations, are being taken over by the Extension Service, where they rightly belong, thus providing the research men in these fields time for better controlled and more basic studies. Changes in this direction should of necessity be slow, but present trends indicate that they are also sure—a very encouraging sign of progress.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

Consumer Demand for Eggs. (Lorian P. Jefferson). The collection of data for this study is largely completed. General tabulations have been made but no attempt to draw conclusions as yet. The study looks to a determination of the demand for different grades of eggs, the proportion of grades handled, the opportunity for the local producer in local markets, and the differences between demand in different markets.

The Economic Worth to Growers of Different Varieties of Apples. (Lorian P. Jefferson). This study is still under way, having been planned to cover at least five years. Obviously no conclusions can be drawn until the end of the period.

Competition Between Apples and Other Fruits. (Lorian P. Jefferson). The study, involving many statistical correlations, actually reveals little direct competition between apples and any other of the most common fruits.

However, it may be questioned whether the statistical data tell the whole story. While statistics show almost no influence of the supply and price of oranges on the price of apples, it is true that the per capita consumption of apples is declining. Apparently, also, the type of demand is changing, and apples are being used for different purposes since the orange has become so largely the fruit on our breakfast tables.

The price variations of Baldwin apples in Boston are chiefly determined by three factors not related to other fruits: the size of the United States apple crop, the size of the New England crop, and the general level of prices. Of these the size of the United States crop is the most important factor.

The price of McIntosh apples is, however, little influenced by the total volume of apples on the market or by New England production, but is markedly affected by the general level and trend of prices. Correlations of supply and price of various other fruits with the price of McIntosh indicate that no one of these has any noticeable influence.

Part-Time Farming. (David Rozman) The project on part-time farming has been completed and the material published as Bulletin 266.

Recreational and Forestry Uses of Land. (David Rozman). Data on land values, taxation, and area held by non-residents were secured from the assessors' books in 71 towns, representing 25 per cent of all towns in the State with a population of less than 10,000. This material is now being tabulated and analyzed as to its bearing on the problems of land utilization.

Detailed information on land utilization was obtained in several towns through personal interviews with assessors, town clerks, real-estate men, and other local people. No definite conclusions from this study will be available until completion of the field work during the next spring.

Factors Affecting Egg Prices. (A. H. Lindsey). Wholesale price quotations on the Boston market were used for the basic material of this study Lack of purchasing power in 1929 and 1930 caused the trend of egg prices, which was already downward, to turn even more sharply downward. The improvement in quality of western eggs has not seriously affected the favorable differential which has existed between prices of western and nearby eggs.

A formula for forecasting peak prices of eggs in November from data on June first has been worked out with an accuracy in results of within two cents, two years out of three. The average price of eggs in April may also be forecast from October—December data with an accuracy of within 2.8 cents in two-thirds of the cases.

The Relation of Quality Factors to Price of Eggs. (A. H. Lindsey). Quality factors used were air cell, weight, condition of yolk, condition of white. Prices were found by purchase of eggs from retail stores in Boston. Three periods were studied—April, August, and November. Weight was of much greater significance in April than in November. Air space was most important in November. Condition of yolk was most important in April. The combined effect of all quality factors on price was of greatest importance in August.

Competitive Factors Influencing the Supply of Market Milk and Cream. (A. H. Lindsey). A study of the Worcester milk shed was made from

records of the City Inspector's Office. Changes in price and inspection had very little influence in changing the milk-shed area. More milk is being produced at great distances from the city and less in the vicinity of the city. The consumption of quality milk is increasing.

Analysis of Market Prices for Massachusetts Vegetables. (H. B. Rowe). A preliminary analysis has been made of the price and supply data which were tabulated last year for ten of the more important vegetables on the Boston market, and a more complete study of asparagus prices has been practically completed. The preliminary analyses indicate that valuable results may be expected for all but two of the ten crops. The asparagus study has furnished quantitative measurements of the relationship between local prices and the two most important price factors, local supply and shipped-in supply, during the period just preceding the local marketing season. Knowledge of these relationships makes possible the interpretation of outlook for local producers, with a degree of accuracy and reliability which could not be attained heretofore.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness). The investigation of mechanically refrigerated storages has been carried on this year along two distinct lines. The phase pertaining to the temperature requirements for satisfactory storage has been continued in cooperation with the Department of Pomology. The results of two years' observation will be available at the end of the present storage season.

The study of another phase of the storage problem was made possible this year through the fact that three fruit growers installed mechanical refrigeration on their farms, and careful observation has been made of the operation of these storages. Different types of equipment have been installed in these various storages, and it has been possible to observe the effect of various types of equipment on the stored fruit. Data on the cost of operation of the various storages are being collected.

Fertilizer Distributors. (C. I. Gunness). Very little work has been done on this project during the present year. It is hoped that more time can be given to this project during 1931.

Test of Low-Lift Pumps. (C. I. Gunness). During the past summer a testing plant was built at the Cranberry Station at East Wareham for the testing of low-lift pumps. This was completed in August, and one pump was tested. The publication of the results will be delayed until additional pumps can be tested.

DEPARTMENT OF AGRONOMY

A. B. Beaumont in Charge

Nitrogen Assimilation by Grasses and Clovers. (A. B. Beaumont and G. Rohde). Additional evidence obtained from solution cultures showed that blue grass, timothy, redtop, English rye grass, and red and alsike clovers assimilated nitrate nitrogen better than that from ammonium sulfate and urea, as judged by growth. In the early stages there was little difference in the growth of the several grasses, but differences appeared in the later stages. With the clovers, the differences due to form of nitrogen appeared earlier and were more pronounced.

Ecological Study of Pasture Vegetation. (A. B. Beaumont, E. F. Gaskill and R. W. Donaldson). The old experiments have been continued and new ones added for the purpose of comparing different carriers of nitrogen and different amounts of lime and other calcium compounds. Results of this year indicate that very little effect may be expected from minerals (lime, phosphoric acid and potash) the same year they are applied as a top-dressing, whereas all forms of nitrogen used are more or less effective the first year. Similar evidence regarding response to minerals and a nitrogen fertilizer (Chilean nitrate of soda) were obtained from ten outlying fields in Worcester County.

Additional Pasture Experiments. (A. B. Beaumont, R. E. Stitt and R. C. Foley). In a palatability test it was found that two Holstein cows chose pasturage as follows: (1), white clover; (2), timothy; (3), redtop; (4), blue grass. There was little if any effect of different fertilizer treatments on palatability although there was some indication that grass from plots which received the largest amount of nitrogen was preferred by the animals. On certain of the Hohenheim plots it was likewise observed that seedings containing a high proportion of timothy were preferred by dairy animals.

In an experiment in which two carriers of nitrogen were used as top-dressing for a mossy pasture, it was observed that Chilean nitrate of soda acted as a mild toxin for moss. To a considerable extent moss was permanently killed without injuring the desirable vegetation.

Legume Veriety Tests. (A. B. Beaumont and R. E. Stitt, cooperating with E. A. Hollowell, Bur. of Plant Indus. U. S. D. A.).

Alfalfa.—Test No. 1 was brought to a close on account of weediness, and the field plowed after spring data on stand were obtained. These data were in substantial agreement with those reported last year. The experiment has shown that for a period of at least three years the common varieties of alfalfa coming from such states as Utah, Kansas, and the Dakotas may be expected to be in the same class as Grimm and other variegated varieties as respects winter-hardiness. Test No. 2 also was terminated on account of weediness (mainly grasses). This test has given data on winter-hardiness similar to those of Test No. 1, but covering more varieties. Ludak, Turkestan and Arizona were definitely poor in stand after two winters; California, South African, and Colorado were good; and Grimm, Ontario, Hungarian, Dakota Common, Hardigan, Disco, New Mexico, Italian, Utah, Kansas, and French were the best.

Further, this test has demonstrated that it is unwise to seed alfalfa on sod land in Massachusetts without the intervention of at least one year of tilled crop or fallow to kill troublesome weeds, especially the grasses. From Test No. 3, seeded in 1929, data on stand and yield were obtained this year. Yields per acre for two cuttings, one year after seeding were:

4-5 tons: Ontario, Hardigan, Dakota Common, Hungarian, Italian.
3-4 tons: Dakota 12, Disco, Utah, Argentine, Nebraska, Turkestan, Kansas, New Mexico, Ladak.
2-3 tons: Arizona, South African.
1-2 tons: Hairy Peruvian.

Soy beans.—Of 20 varieties of soy beans, the following 10 yielded the most hay in decreasing order: Dunfield, Manchu, Habaro, Mansoy, Virginia, Medium Green, Harbinsoy, George Washington, Illini, Pinpu. Seven of these were among the highest yielding 10 varieties of last year.
Field Peas.—Of 5 varieties tested, Chang led in yield of hay, followed by Golden Vine, O. A. C. 181, Wisconsin Common, and Multiplier, in order.
Vetch.—Spring sown vetch varieties yielded hay in the following order: Oregon Pearl, Oregon Common, Smooth (15851), Hungarian, Hairy (15760).

None of these annual legumes—soy beans, field peas, vetch—with only one cutting, yielded as much hay as well-adapted alfalfa varieties with two or more cuttings a season according to these tests. Therefore, it appears that such annual legumes should be considered mainly as emergency substitutes for the higher-yielding alfalfa and clovers.

Method of Applying Fertilizer to Corn. (A. B. Beaumont, E. F. Gaskill and R. E. Stitt). This is the third consecutive year that a field test of methods of applying fertilizer to corn has been made. The work was done according to a plan for cooperative work sponsored by a joint committee representing the American Society of Agronomy, National Society of Farm Equipment Manufacturers, American Society of Agricultural Engineers, and National Fertilizer Association. The results of this year are in general agreement with those of preceding years; namely, that fertilizer applied in the hill gives better results than the same, and in some cases, larger amounts broadcast. Fertilizer applied in the hill at the rate of 500 pounds was superior to 500 pounds or 1000 pounds broadcast.

Field Experiments with Onions. (A. B. Beaumont and M. E. Snell). Most of these experiments were redirected last spring in the light of results of the last five years. The crop was started from sets instead of seeds as in previous years. Cover crops were omitted this year, the comparison of muriate and sulfate of potash was dropped, and certain changes were made in the study of fertilizer ratios.

In the lime series, where lime was applied in 1925, there was a progressive increase in yield from applications of 2 up to 6 tons of limestone per acre. In two other series one of which received lime in 1925, the other in 1928, the yield from the later application was superior to that from the earlier, indicating that when lime is used in moderate amounts, the applications should be more frequent. Experiments on the substitution of superphosphate for a part of the lime gave results which indicate that superphosphate can take the place of little if any of the required lime, and at present prices of these materials there would be no economy in the sub-

stitution. All the experiments thus far indicate that lime is indispensable for successful onion production on the soils of the Connecticut Valley.

In the old fertilizer ratio series, the 4-12-8, which has led in former years, was inferior to the 4-8-4 and about equal to the 4-8-8. (Figures refer to percentages of NH_3 (old basis), P_2O_5, and K_2O, respectively.) The highest yield was from the 4-8-4 with later side dressing of nitrate of soda equivalent to a 2-0-0, and the lowest from 2-12-8. It is quite possible that the substitution of sets for seed influenced the effect of fertilizers. The 4-7-4 with a side dressing of fish (2-1-0) gave a low yield. These results with additional nitrogen as side dressing are similar to those of last year, but cannot be explained in the same way; last year was unusually dry, while in 1930 the rainfall during the growing period of the onions (sets) was slightly above normal. In the lime series the 4-12-8 was superior to the 4-8-4, and in the old cover crop series the 4-12-8 was superior to the 6-8-8. Considering the results of this experiment for the six years of its duration, it would seem that for land which has not been intensively fertilized for several years previously, a fertilizer high in prosphoric acid and potash, something like a 4-12-8, is needed for at least the first several years of onion growing. Fertilizer has been applied at the rate of 2500 pounds per acre, a comparatively high rate, and it is quite probable that a cumulative effect of previous years is beginning to manifest itself.

A field experiment with onion sets of three size groups demonstrated the superiority of sets of medium size. Sets from one-half to three-fourths inch in diameter yielded almost twice as much as those one-fourth to one-half inch, and slightly more than those three-fourths to one inch. The medium group threw less than 1 per cent seed stalks, the large sizes 72.9 per cent, and the smallest none. The largest sets produced 33.0 per cent multiple bulbs, medium sets 1.4 per cent, and smallest sets 0.12 per cent. About three times as many bushels were required to plant an acre with large sets as with medium-sized sets. Altogether, the results were strikingly in favor of medium sets.

Onion breeding work was continued on lines previously described.

Nitrogen Assimilation by Tobacco. (A. B. Beaumont and G. Rohde). Further evidence has been secured from solution cultures which supports statements made in the last report that nitrogen in the form of nitrates is better assimilated than in the form of ammonia, urea, and certain organic forms. This nutritive relation prevails when the entire growing period of the plant is considered, although there appear to be stages of growth when ammonia is assimilated as well as nitrate, if not better.

Field Experiments with Tobacco. (A. B. Beaumont and M. E. Snell). 1930 has been the best year for the growth of tobacco since the field experiments were started seven years ago, with the best plots producing slightly more than 1 ton of cured leaf per acre, and all plots averaging around 1800 pounds per acre. The highest yield, averaging 1998 pounds per acre, was from a series of 10 plots which received 2625 pounds of tobacco fertilizer analyzing 4.1 per cent N, 4.0 per cent P_2O_5, and 5.0 per cent K_2O, and 10 tons of manure. Five plots which had a cover crop of redtop were next with an average yield of 1936 pounds, followed by those which had timothy and rye as cover crops. As in previous years, tobacco yields were poorest in the animal husbandry rotation (corn, timothy or clover, and tobacco), yields being 1201 pounds after timothy and 1326

after clover. It has now been established that this particular rotation is unsuitable for tobacco, producing symptoms of a malady known as brown root-rot. It remains to determine the underlying causes of the effect, and efforts are now directed particularly to that study. With that in mind the field experiments were redirected in the spring of 1930, the cash-crop rotation being replaced by a duplication of the animal husbandry rotation, and the so-called "criss-cross" rotations dropped.

In an experiment involving different quantities of nitrogen, phosphoric acid and potash remaining constant, 164.5 pounds nitrogen per acre (200 pounds ammonia) gave the highest yield, followed in order by 205.6, 123.4 and 61.7 pounds nitrogen. From this and previous years it seems that for Massachusetts conditions 100 to 150 pounds of nitrogen are necessary for maximum yields of tobacco.

In a further comparison of different carriers of nitrogen, ammonium sulfate produced more tobacco than sodium nitrate, cottonseed meal or the regular mixture containing several forms of nitrogen. Furthermore, and of particular interest in view of results of previous years and other experiments, yields were slightly greater from plots which had one year of timothy preceding tobacco than from the plots which had tobacco the previous year. However, all yields were good.

The following miscellaneous tests were made on a small scale, too small to give more than indicative results:

(1) Both Nitrophoska (15-30-15) and regular tobacco fertilizer containing considerable cottonseed meal, plus magnesium sulfate, failed to produce normal crops of tobacco without lime, when used on a very acid soil (pH about 4.5).

(2) With potash omitted from the regular tobacco fertilizer, but supplied in ground tobacco stems, a good yield of tobacco was obtained.

(3) Colloidal phosphate at rates of 1000 and 2000 pounds per acre, in addition to the regular fertilizer mixture, slightly increased yield.

(4) Milorganite, an organic fertilizer made from processed sewage, proved a good substitute for the more expensive cottonseed meal, producing 1801 pounds per acre. It remains to be seen what the quality of the crop will be.

(5) Fertilizer applied in the row produced slightly more than an equal amount applied broadcast. One-half the standard ration in the row produced 1663 pounds, which compares with 1859 pounds from a full ration broadcast. This is the first year of this experiment and results are only indicative; but in view of results from a similar experiment with corn, it is worth repeating.

Magnesium Requirements of Crops. (A. B. Beaumont and M. E. Snell). This investigation was continued in pot and field experiments according to plans made by J. P. Jones. No outstanding symptoms or depression of yields were obtained in either case. It is now suspected that, except in cases of exceptional deficiency in soil magnesium, plants will hardly be affected in dry years or the next year or two following dry years, owing to the supply of native magnesium through the natural weathering processes. It is planned to continue this investigation.

DEPARTMENT OF BACTERIOLOGY AND PHYSIOLOGY

G. E. Gage in Charge

Nitrogen-Fixation in Relation to Leguminous Crops. (James E. Fuller). Previous work on phases of this subject has been reported during the past year in *Soil Science*, Volume 30, July, 1930, under title of "Nitrogen-Fixation in Field Soil under Different Conditions of Cropping and Soil Treatment." During the course of this investigation the data indicated the possibility that the lime applied may have been responsible for the variations in the amount of nitrogen fixed by the soil from the different plots of the field. The hydrogen-ion concentration of the soil from the various plots showed no marked variation, although the quantity of lime applied varied widely. Therefore, there is a possibility that lime may have some relation to Azotobacter metabolism other than the neutralization of acidity.

Synthetic media have been studied in the laboratory during the year to ascertain the influence of different calcium compounds on the amount of nitrogen fixed by the different strains of Azotobacter. These experiments are being repeated. Plant-house experiments are being conducted in which soil is treated with the calcium compounds employed in the synthetic media, these compounds including salts varying in their ability to neutralize acids. The purpose of the investigation is to study the influence of the calcium in the presence and absence of combined nitrogen.

Another phase of this project has had to do with distribution of cellulose-decomposing activity in the soil of the experimental field. The data at present appear to correlate the nitrogen-fixing activity of the soil from the different plots of the field.

Besides work on this project, a cooperative experiment has been in progress with the Department of Botany. This has had to do with the effect of temperature on the utilization of nitrates by cellulose-decomposing organisms. The data obtained thus far indicate that from the laboratory standpoint soil known to contain active cellulose-decomposing organisms will bring about decomposition of cellulose within a certain space of time. Decomposition was less active at temperatures below 15° C. Data from the pot experiments will be found in the report of the Department of Botany.

Laboratory Service. (Ralph L. France). During the past year the Laboratory Service has given assistance to local milk inspectors and milk dealers throughout the Connecticut Valley. Towns and a few cities have called upon the laboratory for monthly tests of all milk sold within their boundaries. This phase of service has grown into a health control service not only through the medium of laboratory tests but also through information given in personal interviews with dealers and inspectors and by inspections of dairy barns.

Samples of water from private supplies from many parts of the State have been submitted for bacteriological analysis to establish their purity for drinking purposes. Fifty per cent of all the samples analyzed during the year were unsafe for human consumption. This condition shows no great improvement over previous years, and indicates that there is need for active education concerning the location and construction of rural

water supplies. It might be of value, if the laboratory appropriation could be increased sufficiently to finance the undertaking, to make sanitary inspection of the water supply and environment in some of these districts having unsafe water.

The legume culture collection has been kept intact and propagated as in past years, for the purpose of distributing to farmers needing this material for legume inoculation. Nearly all cultures furnished were for inoculating alfalfa.

The miscellaneous examinations made during the year include examinations of milk for garget, streptococci and other organisms causing inflammation of the udder, chemical analyses of milk, and examination of food products for organisms causing unnatural spoilage.

The Indol Tolerance of the Colon-Aerogenes Group of Bacteria as a Possible Means of Differentiating Fecal and Non-Fecal Strains Occurring in Drinking Water Supplies. (Ralph L. France). The work to date indicates that in order to establish a more uniform set of results for the determination of the possible use of the indol tolerance as a test, it is necessary to make some changes in methods and a more complete study of the biochemical activities of the various strains. With these studies followed through, it is anticipated that the difficulties already expressed may be eliminated, making it possible to obtain more consistent results.

DEPARTMENT OF BOTANY

A. Vincent Osmun in charge

Tobacco Black Root-Rot. (W. L. Doran). Soil in plots last limed in 1923 still had pH values favorable to infection by Thielavia in 1930. Neither alfalfa nor timothy was more effective than tobacco in lowering the pH value of over-limed soil. Soil acidity of limed plots was increased somewhat even four years after the application of sulfur. As in previous years, there was less black root-rot in limed plots to which sulfur or acids were applied in 1926 and 1927 than in limed plots not acidified.

There was not much, if any, less black root-rot of tobacco following the hay crops than in plots of continuous tobacco.

Yields of tobacco in plots limed were 27 per cent less than yields in plots not limed. Loss caused by lime applied in 1923, has been decreasing since 1925. Increased yields in limed plots resulting from the application of acids or sulfur were less in 1930 than in earlier years.

The application of sulfur to a field in which the soil had an initial pH value of 7.1 lowered the pH value to 6.5, but this was not enough to affect black root-rot or growth of tobacco.

An application of orthophosphoric acid lowered a soil pH value from 5.9 to 5.0, but black root-rot was nevertheless severe. It is apparent that other factors than or in addition to the hydrogen ion concentration of the soil are concerned.

Tobacco Brown Root-Rot. (W. L. Doran). In the second or third year of tobacco following alfalfa, timothy or alsike clover, there was little and in most cases no brown root-rot. The brown root-rot effect of these hay

crops on the tobacco which followed them disappeared after the first year or two of tobacco.

Assuming, for hypothetical purposes, that brown root-rot is associated with certain soil microorganisms, which may result in a deficiency of nitrogen and (or) the formation of toxic substances in the soil, it is conceivably possible that certain inorganic salts applied to soil might inhibit such microorganisms or might inactivate, chemically, such toxic substances. Copper oxide, copper sulfate, copper acetate, lead sulfate, or lead acetate were applied in varying amounts to brown root-rot soil (timothy sod), and in it tobacco was grown. These salts of copper and lead, in the amounts used, were all somewhat toxic to tobacco plants.

Since brown root-rot is worse in some soils than in others, under the same cropping system, work is now in progress with the object of finding some of the relations between brown root-rot and certain characteristics of the soil, including total nitrogen, P_2O_5, organic matter, soluble iron and aluminum, mechanical condition, and water-holding capacity. The chemical work involved is being done in the Fertilizer Control Laboratory, and tobacco is being grown in all (12) soils.

A Seedbed and Field Survey of Tobacco Diseases in Massachusetts. (W. H. Davis, O. C. Boyd, and W. L. Doran). In a tobacco disease survey of the State, 50 seedbeds and about 100 representative fields were inspected. The results may be briefly summarized as follows:

Seedbed Survey

(1) The soil was sterilized in 25 per cent of the seedbeds.

(2) Twenty per cent of the seedbeds were sprayed or dusted; this practice was followed by nearly everyone planting ten acres or more.

(3) Growers who sterilized their seedbeds were rewarded with superior plants and fewer losses in the crop from wildfire, mosaic and other diseases.

(4) In one instance where a few plants from a bed infected with wildfire were transplanted to a fourteen-acre field, 30 per cent of the plants in the field became infected, causing appreciable loss at harvest.

(5) Growers who have their seed "blown" believed it to be a good investment, permitting use of less seed and insuring better and earlier plants.

Field Survey

(1) Wildfire was found in all fields inspected, except ten, with losses from a trace to 20 per cent.

(2) Angular leaf-spot caused by a bacterium (*B. angulatum*) and new to most of the growers was located throughout the area.

(3) Mosaic or calico was the most prevalent disease, as it occurred in nearly every field.

Onion Diseases and Use of Fungicides on Onions. (W. L. Doran). In cooperation with A. I. Bourne, systematic observations were again made in many onion fields, and for the second year spraying and dusting experiments were conducted. There was neither blast nor mildew here in 1930.

Yields were not affected by copper lime dust; but were increased 13 or 16 per cent by Bordeaux mixture 4-4-50, applied 4 or 6 times, respectively, and 17 or 24 per cent by Bordeaux mixture 8-4-50, applied 3 times or twice, respectively.

Onion Blast (L. H. Jones). By artificially controlling the environment of growing onions, it was possible to produce an injury to the plants resembling blast. Reduced light, high relative humidity, and a wet soil for a period of ten days was sufficient to make the plants blast when exposed for a few hours to intense sunshine and an atmosphere of low relative humidity. Absence of blast in the field this year precluded the possibility of comparison with that condition as it occurs naturally.

Eggplant Wilt. (E. F. Guba, Waltham). Since the last report, study has been confined to the pH relations of the causal organism and host. On slides in Petri dishes aluminum sulfate in 1-100 to 1-500 dilutions, inoculated sulfur, and monohydrated copper-lime dust (20-80) destroyed the viability of the spores. Nutrient media acidulated with sulfuric acid completely inhibited growth of the pathogene at pH 3.7, and the rate of growth increased in proportion to an increase in the pH value of the growing medium. Retardation of growth occurred below pH 4.5. However, the increase in growth of the pathogene due to but slight decreases in acidity between pH 4.0 and 4.5 was significant.

Aluminum sulfate and inoculated sulfur were compared with respect to their effect upon the growth of eggplants and the control of the disease. Wooden boxes holding four gallons of soil were used and the acidifying agents were added in increasing quantities. Inoculated sulfur produced a rapid increase in acidity, while at least three times as much aluminum sulfate was required to obtain the same effect. With aluminum sulfate, a range of pH 4.7-5.0 showed no effect upon the growth of eggplants. Infection occurred at pH 5.0 and higher. Below pH 4.7 growth became poorer as the pH value of the soil decreased. With inoculated sulfur, all of the plants were infected at a soil pH of 4.3, and one-third of them at pH 4.0. At pH 4.0 growth was fair, and at pH 3.5-3.6 the plants were killed.

The effect of field applications of chemicals on the control of the disease and the growth of the host was studied. The plants were grown in soil sterilized with formaldehyde, and the field to which the chemicals were applied had been used for eggplants for four years in succession. The results revealed the failure of inoculated sulfur and aluminum sulfate to control the disease when applied at a rate in excess of the tolerance of the host. No results were secured which could be construed as a basis for suggesting acidification of infested soil as a method of controlling eggplant wilt. In the experiment reported, eggplants on land in sod for five years gave the best growth and the best yield in spite of the high percentage of infection. The existing practice of using old sod for eggplants remains the only reliable and practical method of control.

Cucumber Downy Mildew. (W. L. Doran). The weather of the season seems to have little relation to the date of the first appearance of this disease in the field. In six consecutive years (1925-1930), downy mildew has always appeared here within the first two weeks of August.

Bodies resembling oospores have been found, but attempts to germinate them or cause infection with them were without result. The means of overwintering of *Peronoplasmopara cubensis*, therefore, remains undertermined.

It was found that conidia produced in any dewy night do not live after the sun dries the dew in the morning. Infection in the absence of rain, there-

fore, must occur the same night or the same morning as that in which sporulation has brought the infecting conidia into existence.

Greenhouse cucumbers were injured by dusting with sulfur but not by spraying with Bordeaux mixture 1-1-50, 1-5-50, 2-2-50, 2-10-50, 4-4-50, 3-10-50, or 4-0.8-50, nor by copper acetate, Pickering spray, or milk of lime.

Cucumbers which had been sprayed, the day before, with Bordeaux mixture 1-1-50, 2-2-50, 2-10-50, 3-3-50, and 3-10-50 were inoculated with a suspension of the conidia of *P. cubensis* in water. There was no infection of any of the plants so treated, although every leaf of check (unsprayed) plants became infected. In the greenhouse, Bordeaux mixture, 1-1-50 is probably adequate in preventing infection of cucumbers by this fungus.

Strawberry Gold Disease 1930. (E. F. Guba, Waltham). Experiments are under way to determine the nature and manner of spread of the disease. The possible relation of insects to infection is being determined by W. D. Whitcomb. The value of roguing and the selection of healthy plants for the succeeding planting are being considered as means of control. Data from the experiments undertaken will be available in 1931.

Tomato Leaf-Mold. (E. F. Guba, Waltham). Work on this project during the year has been confined to demonstrations of the control of the disease through air management based on knowledge of the temperature and humidity relations of the fungus. Adequate air circulation to prevent excessive temperatures and to insure rapid removal of water of transpiration from the leaf surfaces is essential to the control of the disease. From June to September, inclusive, when heating is not practiced, inside conditions should parallel outside conditions as nearly as possible; likewise during warm intervals in May and October, and when the outside temperature does not drop below 50°F. With a daily minimum of less than 50° F. outside, heat to provide an inside temperature of 60°-65° F. with a little ventilation is important. After the middle of November ventilation is not necessary so long as the inside temperature is less than 80° F.

Old-type greenhouses often lack adequate means of ventilation. Experiments have shown that for these houses especially, and for modern types where hand control is not efficient, automatic control of humidity will remove the disease as a factor so far as it influences the yield. The system involves a series of exhaust fans and pipe heat, the movement of the former and the flow of the latter called for independently or in unison by a hygrostat, set (for tomato leaf-mold) to demand heat and exhaust air when a maximum relative humidity of 80 per cent is reached. A low thermostat set at 60° F. guarantees the minimum growing temperature, and a high thermostat set at 70° F. determines the range of temperature within which heat may be expected to operate the hygrostat for its control of the humidity. Above this range the humidity is controlled by the exhaustion of air only. Ventilation was necessary only as the inside temperature rose above 70° F. In the fall and winter of 1929-30, automatic humidity control gave 17 per cent less infected foliage than automatic temperature control, and in the fall and winter of 1930-31 (up to December 1) 10 per cent less than automatic temperature control. Since the comparison was made with conditions which were subjected to careful hand control except for temperature which was automatically regulated, and in a greenhouse with ample ventilating area, the small difference in favor of automatic humidity control is significant.

Eradication of Nematodes in Greenhouse Soils. (L. H. Jones). A mixture of equal parts by weight of calcium cyanide (Cyanogas) with paradichlorobenzene, incorporated in the soil of a ground bed in two applications with an interval of seven days, successfully eradicated nematodes. Each application was at the rate of 2400 pounds per acre. Twenty-nine days after the second application, tomatoes were planted in the bed. The first crop was adversely affected by the paradichlorobenzene. The second crop was excellent, both in foliage growth and production. The bed has remained free from nematodes for more than a year while beds on either side have been severely infested. Though this treatment is not practical, the results seem to promise some measure of success for the effort to apply the principle of dry chemical applications to the eradication of nematodes in the soil.

Ridding Soil of the Narcissus Nematode. (L. H. Jones). The narcissus nematode (*Tylenchus dipsaci*) is quite distinct from the parasitic species found in greenhouse soils. The former has been eradicated by treatments that failed entirely when used against the greenhouse nematode. Soil infested with the narcissus nematode was freed of this organism by each of the following treatments: steam in one application, chloropicrin (tear gas) in one treatment, Cyanogas in two treatments, and a combination of Cyanogas and paradichlorobenzene in one treatment. Narcissus was grown on the treated soils and the bulbs stored until autumn. Efficacy of the treatments was determied by examination of the bulbs.

Carnation Blight. (E. F. Guba, Waltham). The causal fungus (*Alternaria dianthi* S. & H.) does not survive the second winter in the field, indicating the importance of a two-year rotation. Commercial varieties show different degrees of susceptibility to blight, and the reaction of all types to the disease has been carefully studied. In general, the Matchless and related broad-leaved types are very susceptible.

The early occurrence of the disease is often noted in the propagating house and in the flats, but the value of Bordeaux treatments could not be shown in the absence of disease as a factor where the experiments were conducted in 1930. Injuries to the leaf tissue by red spider, artificially with the needle, and by the knife were shown to favor infection of the leaves. Pruning the cuttings, therefore, increased the danger of infection.

Laboratory experiments with fungicides have demonstrated the superiority of Bordeaux mixture and calcium arsenate sprays in preventing germination of the spores and infection of potted plants. A variety of dust mixtures containing combinations of naphthalene, copper sulfate and calcium arsenate in combination with lime or sulfur as fillers prevented spore germination, but on potted plants the most effective protection against infection was obtained with dust mixtures containing calcium arsenate. Of the dusting mixtures used in the field, calcium arsenate, monohydrated copper sulfate and lime gave the best results; but better control was obtained with copper sprays; e.g., Hammond's copper solution, sal soda Bordeaux and caustic soda Bordeaux. Sal soda Bordeaux proved superior to the other sprays used, but none of the sprays or dusts used in 1930 gave satisfactory control of the disease.

Experiments in progress show that loss from disease after the plants are housed is influenced by the prevalence of disease on the plants in the field,

late benching, overhead watering for controlling red spider, over-watering, and high house temperatures. A comparison of overhead watering and naphthalene fumigation for combating red spider showed 27 per cent increase in production of flowers in favor of naphthalene fumigation. The difference is attributed to a higher mortality of plants from Alternaria and Fusarium where water sprays were used for controlling red spider, and to better growth among plants subjected to naphthalene fumigation, resulting from particular house atmospheric conditions attendant with the use of naphthalene.

Plant Diseases not Previously Reported in Massachusetts. (O. C. Boyd and W. H. Davis). Leaf-blight of corn, caused by *Helminthosporium turcicum* Pass., on Golden Bantam, Yellow Dent, Stowell's Evergreen; leaf-spot of *Lupinus polyphyllus*, caused by *Alternaria* sp.; Botrytis wilt of *Lupinus polyphyllus*, caused by *Botrytis vulgaris* Fr.; fruit-drop of grape, caused by *Pestalotia uvicola* Speg., especially severe on Brighton grape; twig-blight of American bladdernut, caused by *Coryneum microstictum* Berk. & Br.; rust of Iris sp., caused by *Puccinia iridis* (DC.) Rabh.; halo blight of Lima bean, caused by *Bacterium medicaginis* (Sack.) EFS. *phaseolicola* Burk.; bacterial leaf-spot of cabbage and cauliflower, caused by *Bacterium maculicolum* McC. (apparently); angular leaf-spot of cucumber, caused by *Bacterium lachrymans* Smith & Bryan; bacterial leaf-speck of muskmellon, undescribed and undetermined; bacterial leaf-spot of summer squash, caused by *Bacterium cucurbitae* Bryan; leaf and fruit-spot of pepper, caused by *Bacterium vesicatorium* E. M. Doidge; bacterial wilt and root-rot of alfalfa, caused by *Aplanobacter insidiosum* McC.; stem-rot of sweet clover, caused by *Corticium vagum* Berk. & Curt.; limb canker of blue spruce, caused by *Cytospora* sp., previously observed for many years but cause not determined; wilt of Japanese barberry, caused by *Verticillium alboatrum* Reinke & Berth.; bud-blight of Gardenia, cause undertermined, associated with the presence of mealybugs and probably bacterial; bacterial blight of soy bean, caused by *Bacterium sojae* Wolf.; leaf-spot of Zinnia (Bacterial; undet.); ring-spot of tobacco (Virus).

Forcing Gladiolus with the Aid of Artificial Light. (L. H. Jones). Gladiolus corms of the variety Crimson Glow, kept in cold storage during the summer, were planted August 21 and September 11. All plants received the normal daylight under glass. Half the plots were curtained off at night and each of these received electric light from a 100 watt bulb. In the planting of August 21 there was an increase of 100 per cent in the number of spikes produced in the artificially lighted plots compared with the non-illuminated plots. In the planting of September 11 fewer spikes were produced in the lighted plots than in the lighted plots of August 21, but no spikes at all were produced in the plots not receiving light. Several of the spikes were in full bloom for Christmas Day. In a later experiment an effort was made to determine whether better results could be obtained from side lighting as distinguished from overhead lighting. Both 100 and 300 watt lights were used. No measurable differences were noted.

The Storage of Gladiolus Corms. (L. H. Jones). Gladiolus corms are harvested in the early autumn and placed in storage until the following spring. Forcing gladiolus in the winter has made it necessary to carry the corms in cold storage during the summer, thus prolonging the dormant period. A cold storage temperature of about 38° F. gave the best results

and usually 100 per cent germination was obtained. Experiments have shown that corms properly stored may be kept in cold storage two years, and positive blossoming results have been obtained after three winters and two summers in storage. The corms should be in shallow trays to permit free circulation of air. An experiment is now under way to determine the maximum time corms may be stored.

Influence of Light Quality on Plant Growth. (A. V. Osmun). The experiment to test the effect of Vita glass on plant growth and development has been continued with somewhat contradictory results. In one test, radishes grown under Vita glass averaged 1.7 grams or 10 per cent less in weight than those grown under ordinary glass; while in another test, the difference was 3.5 grams or 14 per cent in favor of the Vita glass. Lettuce under ordinary glass weighed 3 per cent more than that grown under Vita glass. Compared with previous tests in which radishes under Vita glass increased 71 per cent in weight and lettuce 76 per cent over the plants under ordinary glass, the results are very inconsistent. The tests will be continued.

The Effect of Decomposing Paper on Plant Growth. (L. H. Jones). Nitrogen deficiency in a plant may result from decomposing paper in a soil or from a plant container made of paper in contact with the soil mass. This has been well established by incorporating paper mulch in a soil and also with improperly water-proofed paper flower pots. When paper mulch is incorporated in a soil, nitrogen starvation may ensue unless an available form of nitrogen is supplied to the plant. Using tomato seedlings in four-inch pots with and without paper mulch in the soil, it was noted that all plants made equally good growth for one month. At the end of the second month, the plants in the soil containing no mulch were 33 per cent taller than plants in a soil with mulch, and averaged nine axillary shoots. The plants in the soil containing mulch were without axillary shoots and were more yellow in color, indicating a lack of nitrogen due to decomposing cellulose.

The problem of obtaining good plants from paper pots is not one of soil acidity nor lack of porosity. It has been demonstrated that better plants can be grown in undrained glass containers than in porous clay pots. When plants become yellow in paper pots, they can be made to resume normal growth by an application of sodium nitrate. If the fibers in the paper pot are so protected that decay is impossible, plants equal to those grown in porous clay pots may be grown in these pots.

Chlorosis of Snapdragon caused by an Excess of Lime. (L. H. Jones and H. D. Haskins). Snapdragon plants grown in a greenhouse soil made from a sandy subsoil mixed with manure and lime became very chlorotic. As the new leaves were yellow in the early stage of development the cause seemed related to a deficiency of iron in the plant. When tested for reaction, the soil was decidedly alkaline (pH 7.9). Pot work indicated that the trouble could be overcome by leaching the soil with a 1 per cent solution of sulfuric acid at the rate of one gallon per square foot. The soil so treated was leached of acid with an equal volume of water and then supplied with a complete fertilizer mixture. In the absence of the sulfuric acid treatment, fertilizer materials of superphosphate, potassium sulfate, and ammonium sulfate, either alone or together, were ineffectual. The iron of ferric chloride was not assimilable. Although snapdragons

suffered markedly from the high amount of lime, stocks were quite tolerant and did well.

The Effect of Temperature on the Nitrate Content of the Soil and Plant Growth in the Presence of Decomposing Cellulose. (L. H. Jones and James E. Fuller). One per cent of cellulose in a soil maintained at constant temperatures ranging from 7° to 35° C. definitely affected the nitrate content of the soil. The tomato, because of its upright habit, was employed as an indicator plant. If the soil is one with a high level of fertility, the plants are unaffected by the reduction in nitrates and the differences obtained in plant growth were directly the result of temperature, a marked increase in growth occurring at a temperature of 22° C. and above. However, if the soil had a low level of fertility, temperature ceased to affect plant growth and the response of the plant was dependent upon the available nitrogen. The presence of decomposing cellulose in such a soil reduced the dry weight of the plants as much as one-half to two-thirds of the weight of plants grown in a soil to which no cellulose had been added. With a soil rich in nitrogen the addition of cellulose caused a considerable depletion of nitrates at the lower temperatures, while at higher temperatures nitrification was sufficiently active to replace the nitrate used by the cellulose decomposing organisms. In a poor soil to which a considerable amount of cellulose was added the ratio of nitrate to cellulose appears to have been so small that temperature had little influence on the degree of nitrate depletion, the rate of nitrification, or the response of the indicator plant.

Temperature Control Tanks. (A. Vincent Osmun and L. H. Jones). Many changes and improvements have been made in the apparatus for maintaining constant soil temperatures. Better results are now obtained with less attention and lower maintenance cost. In conducting an experiment of three months' duration no adjustments were necessary except the replacement of a loose nut on one of the contactors. Each of the thirteen compartments maintained its temperature throughout the period. This apparatus is available for many types of research. It has been of invaluable assistance in the study of the following problems: the smut disease of onions, black root-rot and brown root-rot of tobacco, nematode galls, growth of gladiolus in the greenhouse, soil temperature in plant containers, Verticillium wilt of eggplant.

An Electric Steam Generator for Sterilizer Retorts. (Howard Bidwell and L. H. Jones). This steam generator was developed to fulfill the requirements of obtaining a sterilizing pressure quickly, and is a decided departure from the usual type. About 80 per cent of the water volume in the boiler is available for supplying steam to the sterilizing chamber, without danger of low water, or requiring intake of additional water during the sterilizing process. The principle on which this generator operates is original and eliminates the usual delay in obtaining the required sterilizing pressure. The generator is under automatic control at all times, thus reducing necessary attention to a minimum. The details of its construction and operation are given in a paper entitled "Packed heat from a new type electric steam generator" accepted for publication in *Industrial and Engineering Chemistry.*

THE CRANBERRY STATION

(East Wareham, Massachusetts)

H. J. Franklin in Charge

The station has enjoyed for the first time, during the most active part of the 1930 cranberry season, the effective cooperation of the extension services of Plymouth and Barnstable Counties. These counties together hired a special agent, an experienced cranberry grower of Kingston, Mass., to conduct the cranberry extension work from the middle of May till the middle of August. The work was handled satisfactorily, and more time was available for the station's research work in spite of an increase in the number of extension calls.

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin). Various samples of pyrethrum soap were tested on different kinds of insects to guide manufacturers of these soaps in improving and standardizing their products. Bog tests of pyrethrum soap sprays brought out clearly that such sprays are entirely safe to use on cranberry vines whenever it is safe to spray with nicotine sulfate and soap. They are likely to cause serious loss by blasting blossoms or newly set berries or by stunting small berries if they are applied while the vines are in full bloom or before the berries are well started in growth. Pyrethrum extracts without soap, such as Evergreen, did harm to blossoms and small berry sets in some cases, but were generally much less injurious than pyrethrum soap. The season's experience with pyrethrum soap sprays leads to the conclusion that such sprays are preferable to nicotine sprays for treating the first brood of the black-headed fireworm (*Rhopobota vacciniana*), for they are fully as effective and kill much more promptly. The prompt kill is a great advantage, especially if it rains soon after the spraying is done.

Penetrol, used in sprays as directed by the manufacturer, did material injury when applied to cranberry vines during and just after the blossoming period.

Bog tests showed that it takes an application of sodium cyanide solution about sixteen hours to kill a satisfactory percentage of an infestation of the cranberry root grub (*Amphicoma vulpina* Hentz.). Tests with herring in tubs of water containing samples of treated bog soil showed that the cyanide poison used to treat this grub persists in the soil in considerable strength at least a week. In treating the soil, six ounces of the cyanide had been used to a hundred gallons of water, and the solution had been applied at the rate of a gallon to the square foot. This treatment has proved satisfactorily effective in killing these grubs in all their stages including the flaccid stage that comes just before pupation, but it seems to kill the pupae much less readily. It should therefore always be completed before the grubs begin to pupate.

Submergence tests were conducted with partly grown nymphs of the cranberry black bug (*Plagiognathus repetitus*) and of the false blossom leafhopper (*Ophiola striatula* Fallen). The insects, in tin coffee cans with muslin tied over the tops, were submerged to a depth of about a foot in Spectacle Pond at East Wareham. A complete twelve-hour submergence was not enough to kill all the nymphs of either of these two species; but

eighteen hours killed them all. It appears, therefore, that these pests can be controlled more safely by flooding in June than has heretofore been thought possible.

In cooperation with the Bureau of Plant Industry, a very satisfactory chemical color test was developed for determining roughly the oxygen content of water used in bog flooding. This test is so simple that it may be used readily by cranberry growers.

Cranberry Disease Work. (H. J. Franklin in cooperation with the Bureau of Plant Industry, U. S. D. A.). Forecasts of the very poor keeping quality of the fruit of the 1930 cranberry crop were made by the station. They were based on weather records and incubator tests and proved to be timely and accurate.

Weather Observations. (H. J. Franklin). Local weather observations were made and reported to the office of the Weather Bureau at Boston, and further records bearing on frost forecasting were gathered from various special stations as in previous years.

Forecasts of minimum bog temperatures were made in the frost seasons in the early afternoon and early evening and distributed by telephone as heretofore. Frost conditions were so accurately determined that flooding for frost protection was not once begun unnecessarily at the station bog, and three of the four times that such flooding was done there the water was started on in the middle of the afternoon. No one ever remained at the station to watch conditions after the early evening observations were made, and the amount of injury to the bog from frost was negligible.

Southeastern Massachusetts, in common with much of the rest of the country, had the worst drought during July that it has experienced in a great many years. Advantage was taken of this to gain information about the effects of drought on cranberry fruiting. For this purpose plots were laid off on Early Black and Howes sections on the station bog and were watered with about two inches of water once a week during the drought period. The water was put on with a hose, the open end of which was pushed in among the vines at intervals so as to wet the soil well without wetting the vines. The berries from these plots and from unwatered checks near them were picked on the following dates: Early Black variety on September 6; Howes variety on September 18. The berries from the watered areas were notably larger in all cases than were those from the checks, as shown by the following average cup counts (the inspectors' cup of the New England Cranberry Sales Co. being used):

Variety	Cup Counts	
	Watered Areas	Checks
Early Black	114	140
Howes	145	165

The average quantity of fruit per unit of area was 50 per cent greater by weight and 55 per cent greater by volume from the watered areas than from their checks. The berries from the watered areas had a much better color than those from the checks and were evidently fully ten days ahead in ripening.

Varieties. (H. J. Franklin). The study of cranberry varieties, their

characteristics and correlations received more attention during the year than any other one line of investigation. It was found that the most desirable varieties, as measured by productiveness and disease resistance, seldom or never develop berries with more than four locules, while berries with five or six locules are not uncommon among the fruit of many inferior varieties. As a result of these studies with cranberry varieties, the following conclusions have been reached:

(1) *Disease resistance is a unit.* In other words, varieties that resist one disease notably tend to resist other diseases well.

(2) *Disease resistance is an intimate co-function with productiveness.*

(3). *The significance of the important correlations bearing on productiveness and disease resistance apparently may be expressed by the following formula:*

$$P+R+M=T-W$$

In this formula, P is productiveness as measured by the number (not the quantity) of berries produced to a unit of area, R is the amount of disease resistance, M is the minimum of plant structure necessary for the fruit production, T is the total result of the constructive work done by the vital activities of the plants, and W is the total of the varietal wastes. The following are the leading wastes so far noted and determined:

(a) *Seeds.* Only a few small seeds are necessary. The more numerous and the larger the seeds, the more they tax the plant economy needlessly.

(b) *Wax.* A bloom on the fruit is not essential, and its development seems to be very costly to the vines.

(c) *Sugar.* Much sugar in the berries is not essential.

(d) *Pectin.* This has not been studied much yet, but it is likely to be one of the wastes.

(e) *Excessive vine growth.* as indicated by coarseness of the vines or tallness of the uprights or both.

As M in the above formula should be practically the same for all varieties, the value of P+R necessarily varies directly with the value of T—W; and since the accumulated records and observations of the actual performance of different varieties indicates that the value of P+R is inversely and greatly dependent on the value of W, it seems probable that T varies only moderately on the average. As will be seen, when the value of T—W is low, P can have a high value only when the value of R is low and vice versa.

Through special assistance during the summer months, the photosynthesis of several of the leading varieties was studied. Hydrogen-ion determinations were made of the fruit of a large number of varieties and the pH value was found to be about 2.6 with all varieties at all times during the picking and storage season.

Cultivated Blueberries. (H. J. Franklin). Fairly extensive counts of the seeds of quite a number of cultivated blueberry varieties were made and it was found that the most desirable varieties, as measured by the quantity and size of berries produced, had notably fewer seeds than the others in nearly all cases.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

A Study of Packaged Ice Cream. (K. E. Wright). This project has been continued throughout most of the year, and the results have been tabulated and published as Bulletin 269.

The Effect of Initial Cooling Temperatures on Gelatin in the Aging of the Ice Cream Mix. (K. E. Wright). Work so far completed on this project indicates that much of the texture benefits resulting from aging an ice cream mix are associated with the viscosity imparted by gelatin, and that high initial temperature in the aging period favored the development of greater viscosity. It was also determined that the maximum viscosity was found to be imparted when the mix was allowed to cool from 80°-100° F. to 40° F. without agitation, and that the whipping property was decreased as the viscosity increased.

This work as far as completed indicates that the results of aging an ice cream mix are dependent upon the factors affecting crystallization of the gelatin portion of the product.

Factors Affecting the Aging Time of Ice Cream Mix. (K. E. Wright). Work so far completed would indicate that the solidification of fat in the aging of the mix is a minor factor and that the adsorption is probably the important factor.

Only 50 per cent of the benefits of aging in a 24-hour period are obtained during the first 4 hours, and the rate of adsorption or whip improvement appears to depend on the amount of emulsifying agent available, i.e., a butter mix improves more slowly than a cream mix or one containing egg yolk. A fairly satisfactory relation was found between the surface tension and the ease of whipping. In all cases a decrease in surface tension was noted after a 24-hour aging period. Cream mixes were found to have less surface tension than butter mixes. Buttermilk was found to have a lower surface tension than skimmilk, and the addition of buttermilk to a butter mix lowered the surface tension of the mix and improved its whipping property.

Extractions of egg yolk with various fat solvents indicated that the solvent altered the emulsifying agent. An ice cream freezer was developed which was found to be very useful for experimental freezing and is an improvement over the commercial freezer because of its smaller capacity. Chemical study of the emulsifying ingredients of ice cream mixes is being continued along with cataphoretic measurements of the effects of the ingredients which aid emulsification.

A Study of Frozen Sweet Cream for Use in Ice Cream. (M. J. Mack). This project has been active the last two years and full report is published in Bulletin 268.

The Utilization of Frozen Fruits in Ice Cream. (M. J. Mack). This study is being conducted in cooperation with the Department of Horticultural Manufactures. The third crop of such fruits as strawberries, raspberries, cherries, and peaches is now being studied. This year the fruit has been packed with cane sugar in fruit to sugar ratios of 2:1 and 3:1, with sugar syrup, with invert sugar, and in partial vacuum. Fruits preserved in these different ways are being compared in order to determine their relative merits for use in ice cream.

Use of Gelatin in Ice Cream. (W. S. Mueller). Investigation for new uses of gelatin in ice cream has resulted in developing (1) gelatin fruit cubes, (2) modified Aufait ice cream, (3) filling for ice cream pies and cubes. The same principle is employed in all these uses; namely, the addition of edible gelatin to fruit juice or to a water solution containing fruit acid. Crushed fruits may also be added. The fruit cubes are cut to ¼ inch size and scattered into the ice cream at time of drawing. Modified Aufait ice cream is made by placing layers of jellied fruit juice, with or without crushed fruit, into brick ice cream. The filling for the ice cream pies is similar to the material used in making the modified Aufait ice cream. Some difficulty has been experienced in keeping the jellied fruit juice clear, due to the low temperatures to which it must necessarily be subjected when used in ice cream. This troublesome ice crystallization has been largely overcome by using the correct amount and kind of sugar and also maintaining the correct amount of acidity. A variety of sugars; namely, cane, corn, invert and corn syrup, has been used in various combinations. Freezing point determinations are being made for various sugar-gelatin-H_2O solutions. The addition of jellied fruit juice to ice cream seems desirable from the standpoint of attractiveness which the clear, bright-colored jellied fruit juice gives to the ice cream.

A study of the effect of time and temperature in cooling an ice cream mix upon the behavior of gelatin has been made. Initial cooling temperatures ranging from 0°C. to 60°C. were used. An initial cooling temperature of 20° C. for 4 hours gave the maximum basic viscosity, increased the gel strength, increased melting resistance and improved the texture for the particular mix used. A study is now under way to determine what factors influence the degree of results obtained when using a high initial cooling temperature. The following factors are being studied:

1. Strength of gelatin
2. Amount of gelatin
3. Amount of butterfat
4. Amount of serum solids
5. Amount of sugar
6. Source of butterfat and serum solids

A new type of colloid mill is being used experimentally in place of a homogenizer for processing ice cream mixes. The effect upon the physical properties of the mix and the desirability of the finished product are being studied.

Preliminary experimental work on the value of gelatin in retarding "sandiness" in ice cream has shown that gelatin has a greater value in this respect than is generally conceded.

A number of commercial stabilizers are being used with gelatin in ice cream. Preliminary experiments have shown a mutual precipitation of gelatin with some of the stabilizers and no mutual precipitation with others. Experiments are now being planned to determine the cause for this mutual precipitation.

The Comparative Efficiency of Electrically-operated Tanks Versus Ice in the Cooling of Milk. (J. H. Frandsen). Whether the tank is of home construction or specially manufactured, it is essential that it be of ample capacity; roughly speaking, when filled with cans to full capacity there should still be room for twice as much water and ice as milk. If the tank

is of home construction, there should be at least 3 or 4 inches of cork or its equivalent and this of course must be protected against moisture. Such insulation saves more than its cost in saved refrigeration in one season. Electric cooling of milk is entirely practicable. The machines tested are convenient, reliable, and, if well adjusted, economical, although the probable service cost and annual depreciation charge were not determined. Electric milk cooling tanks are a distinct labor-saving device and are more sanitary than natural ice.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials Which Promise Value in Insect Control. (A. I. Bourne). Further studies were made of the different types of oil sprays with special reference to European red mite control. Red mite infestation was comparatively light throughout all the college orchards. Under such circumstances all the oils gave satisfactory control with but slight distinctions between types.

Quad and triplex nozzles proved to be as satisfactory as spray guns and superior to old-type rod and nozzles. They were superior to guns in maintaining a mistlike spray enveloping the trees, and coverage was practically as rapid. Guns were superior under unfavorable wind conditions.

Weather conditions were favorable during the delayed dormant period. The temperature was somewhat above normal, but not excessively so as in 1929. No injury was noted following any oil spray used.

Of the miscible oils, Sunoco, Scalecide and Dendrol showed their customary high efficiency; well over 95 per cent control. Of the emulsions, Kleenup at 4 gallons to 100 gave 95 per cent control, somewhat better than results in 1929.

Tests of miscible oils combined with commercial copper fungicides and of soapless emulsions with lime-sulfur showed no injury to the trees or lessened insecticidal efficiency of the oils.

Comprehensive tests of relative coverage of different oil sprays and of lime-sulfur, in a block of 15-year-old apples selected because of the uniformity of size and spread of the trees, indicated a considerable superiority of the oils over lime-sulfur in material and time necessary to spray the same number of trees. The differences between the various types of oil sprays were comparatively small, and would not point to appreciable superiority of any one type over another when considered on a commercial basis.

In cooperation with The Pomology Department, tests were made with some of the materials or combinations of materials designed to replace lead arsenate as a stomach poison or to furnish a fungicidal action equal to lime-sulfur and at the same time avoid the toxic effects of the lead arsenate–lime-sulfur combination upon fruit and foliage.

Calcium arsenate in combination with aluminum sulfate and lime-sulfur, with lime-sulfur alone and with the addition of excess lime was used in a block of five varieties of apples which included four of the so-called "New England Seven", namely Baldwin, Northern Spy, R. I. Greening and McIntosh. These sprays were compared with the standard lead arsenate–lime-

sulfur combination used with and without the addition of a casein spreader. The schedule which was followed consisted of a pre-blossom and a calyx spray, two cover sprays, and an apple maggot spray in July.

The aluminum sulfate–calcium arsenate–lime-sulfur combination showed excellent persistence and caused neither injury to foliage nor russeting of fruit.

Calcium arsenate and lime-sulfur showed good adhesive qualities but caused considerable burn to foliage of McIntosh and serious burn on other varieties. With the addition of excess lime burn was not so severe but was present on all varieties including McIntosh. Both sprays caused a considerable drop of leaves during June and July, although to a less degree when excess lime was added.

Slight burn was noted following the lead arsenate—lime-sulfur combination both with and without casein spreader. The varieties showed considerable difference in susceptibility to burn. Injury was most pronounced on foliage of Baldwin and King; least so on McIntosh.

Flotation sulfur and calcium sulfide, two new materials designed to replace lime-sulfur as fungicides, were used in combination with lead arsenate to test their compatability with that material. These were used in blocks of McIntosh, a variety subject to scab, and Baldwin, which is very susceptible to spray burn and russeting. Neither of these materials caused injury to foliage or russeting of fruit on either variety, and both showed good coverage and excellent persistence throughout the season.

The comparative value of these sprays is shown in the following table, based on examination of the McIntosh crop at harvest.

McIntosh Apples, Block A

Treatment	Percentage of fruit showing: Scab	Insect Injury
Calcium arsenate, Aluminum sulfate, Lime-sulfur	0	37
Calcium arsenate, Lime-sulfur	2	20
Calcium arsenate, Lime-sulfur, Excess lime	2	28
Lead arsenate, Lime-sulfur	0	20
Lead arsenate, Lime-sulfur, Spreader	2	14
Check	54	58

McIntosh Apples, Block E

Flotation sulfur, Lead arsenate	0.2	11
Calcium sulfide, Lead arsenate	4	8
Lead arsenate, Lime-sulfur	4	20
Check	55	49

All of the sprays showed excellent control of scab as compared with unsprayed checks. Combinations containing calcium arsenate controlled scab as well as did those containing lead arsenate, but were slightly less efficient against insect pests. Flotation sulfur and calcium sulfide combined with lead arsenate controlled scab as well as or better than the lead arsenate—lime-sulfur spray and showed somewhat better control of insect pests. The record on Baldwins showed similar results except that scab was practically absent in all the sprayed plots.

Control of Onion Thrips. (A. I. Bourne). The dry, hot weather early in the season interfered somewhat with the growth of both set and seed onions and threatened an early and heavy infestation of thrips. Subsequent rains during June and July allowed the plants to make rapid recovery and tended to retard the development of the insects. As a result, thrips were but moderately abundant and caused less injury than in 1929 except in some fields of seed onions adjoining sets.

The seasonal development and activity of thrips were normal and occurred at the usual periods. This insect did not reflect the tendency of the season to be somewhat earlier than usual, which was very noticeable in many crops as well as insects.

Observations, through the growing season, of a field of seed onions at a distance from sets showed the infestation of thrips to be negligible up to July 7, from July 21 to 28 it averaged 25 to 40 thrips per plant, and reached its peak during the week of July 28 to August 4 with an average of 40 to 42 thrips per plant. This coincided very nearly with the point where the plants had reached maximum height. Beyond this point the numbers of thrips fell rapidly. In this field the plants showed little scarring and matured a good crop.

In contrast to this, a field similar to the above but subject to infestation from an adjoining field of set onions was found to be infested early in the season, and by July 7 the number of thrips had reached an average of 35 per plant. By July 14 noticeable injury was taking place. The peak of abundance was reached on July 28 with an average of more than 80 thrips per plant. Plants in this field were not making satisfactory growth and were badly scarred by the insects. Two applications of the nicotine-soap spray reduced the average infestation from 80 to 10. These plants revived somewhat and made new growth but matured a small and rather inferior crop.

Several species of insects predacious on thrips were collected in onion fields. Their numbers were insufficient, however, to make any significant impression upon the infestation.

Four applications of nicotine soap spray were necessary to protect seed onions growing alongside fields of sets. Due to the transferrence of thrips in large numbers from the sets and consequent early colonization of the small, tender plants of seed onions, two of these applications were made earlier than would be necessary on fields not so exposed.

In connection with the study on blast in cooperation with the Botany Department, spraying and dusting experiments were conducted with Bordeaux mixture, commercial copper fungicides and with milk of lime, alone and in combination with nicotine. The weather conditions prevailing during the summer were unfavorable for the development of blast. Mildew was also absent. In the absence of disease, no appreciable increase or de-

crease in yield resulted from dusting. Yields were increased somewhat by applications of Bordeaux sprays. Onion fields in the Valley were observed at frequent intervals during the growing season to note the appearance and extent of disease and insect pests. No instance of blast or mildew was discovered. Dry weather and a moderate infestation of thrips were the chief factors affecting the crop.

Control of the Plum Curculio in Apples. (W. D. Whitcomb, Waltham). Although fruit growers secured better control of the plum curculio in 1930 than in recent seasons, this appeared due to cumulative benefits from improved control measures and timely spray applications rather than to a noticeable increase in natural mortality. The infestation, determined by the number of larvae emerging from one bushel of unsprayed dropped apples in 1930 was 3047, compared with 3137 in 1929, and 2379 in 1928.

Preliminary studies of the effect of temperature on the activity of the plum curculio showed that beetles confined at temperatures above 70° F. made three times as many punctures (1991) as those held below 70° F. (629). The corresponding number of punctures at normal outdoor temperatures was midway between the two extremes (1191).

The effect of maximum daily temperatures on curculio activity as determined from insectary records of the past four years is variable yet shows an average increase of 12 to 27 punctures per day for each 10° rise in temperature.

Beetles feeding on well-sprayed fruit of normal size at the time of the calyx spray lived 10.6 days, and when supplied with normal fruit one week later they lived 10.3 days. With sprayed fruit gathered two weeks and three weeks after the petal-fall period for food, the beetles died in 4.9 days and 3 days respectively.

In both laboratory and field experiments, barium fluosilicate and synthetic cryolite failed to control the plum curculio as well as equal amounts of lead arsenate. Chemical hydrated lime added to the lead arsenate-lime-sulfur combination spray was also less effective than the standard solution. Molasses, fish oil, or linseed oil used as a sticker with lead arsenate was more effective than flour paste or calcium caseinate. An 85-15 sulfur–lead arsenate dust was very effective in the laboratory, but barium fluosilicate-lime, cryolite-lime and naphthalene-lime dusts failed to kill the beetles.

The Spray Residue Problem. (A. I. Bourne). Another season of light rainfall again emphasized the necessity of careful arrangement of the spray schedule in order to avoid arsenical residue on fruit at harvest, in excess of the established limit of tolerance. Rainfall was considerably below normal, although the deficiency was not as great as in 1929. The fact that the greatest shortage was in late July and August was of considerable significance, since it followed the sprays applied in late July for apple maggot and codling moth control, increasing the risk of residue from those applications.

Attention was centered chiefly upon commercial orchards where the schedule included one or two July applications of spray, and on those which were dusted once or more in August. Cooperative tests of different dust materials were made in one commercial orchard.

Analysis of fruit from these orchards shows that in a season such as

1930, Wealthy and similar varieties should not be sprayed later than about July 10. If further protection is necessary, dusts should be used. McIntosh sprayed as late as the third week of July showed a sufficient margin of safety unless heavy, drenching applications were made. Baldwins could be sprayed through July with safety. In all cases where sprays are applied after July 15, any spreading or sticking agent should be omitted and lighter strength of lead arsenate should be used.

Results showed that dusts, if properly applied to McIntosh or Baldwin, could be used as late as August 15 without encountering any difficulty.

The Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb, Waltham). The average over-wintering population of the carrot rust fly at Waltham in 1930 was 39 pupae per square foot where infested carrots remained in the soil, compared with 79 per square foot in 1929, and this should have produced a normal moderate infestation in early carrots. However, the injury by the first generation was negligible, apparently due to the dry, hot weather during the oviposition period in early June. Under laboratory conditions twenty eggs kept in the greenhouse at temperatures always above 70° failed to hatch, while a similar number of eggs in a root cellar maintained at 60°-70° F. hatched perfectly in twelve and thirteen days.

The normal second generation infestation was consequently very light, but a moderate amount of injury was caused in October by a combination of third generation and late second generation maggots. Flies emerged as late as November 10.

Carrots planted May 1 or later were free from injury by the first generation, and the variety plantings showed no definite degree of immunity because of the general light infestation.

Early carrots were very free from injury when grown with or without paper mulch, but those under paper were 20 per cent heavier.

The results of the insecticide treatments in the field were inconclusive because of the light infestation. Carrots grown from seed treated with calomel showed considerable mercury russeting.

Derris dust, both pure and diluted 1-2 with gypsum, was very effective in killing the adult flies, and prevented oviposition, while eight other materials were much less effective, in the laboratory.

All larvae in infested harvested carrots were killed by fumigation with paradichlorobenzine and carbon disulfide. The carbon disulfide used at the rate of 4 ounces for each 100 cubic feet for eighteen hours was the better treatment.

Systematic Study of Oil Sprays. (A. I. Bourne in cooperation with the Department of Chemistry). During the winter, laboratory tests were made of the stability of samples of oil sprays prepared by the Chemistry Department, to determine the relative value of different emulsifying agents as well as of various proportions of oil and emulsifier.

Three samples of oil sprays were submitted for preliminary orchard tests. These consisted of a miscible oil (83⅓ per cent oil), and two types of oil emulsions (66 per cent oil). Two of these gave promising results and indicated the direction for further development of the work.

Apple Maggot Control. (A. I. Bourne). The serious nature of this pest, its abundance in recent years, and the threatened loss of foreign

markets for Massachusetts apples led to a study of different control measures and any adaptations necessary for Massachusetts conditions. The work was done in cooperation with the Extension Service and in conjunction with the county agents.

The twelve orchards chosen for the tests represented, in their size, type, location, etc., a very fair cross section of the fruit growing industry of the State, and in every case maggot had caused serious loss to the crop of the previous season.

The program called for—

(1) Regular and thorough collection of premature drops during the period of maggot infestation, and prompt disposal of such infested fruit.

(2) Treatment, either by spraying or removal, of neglected trees or orchards within 200 yards of the test blocks. In many cases this involved arrangements with neighboring owners, sometimes difficult to accomplish.

(3) Thorough spray or dust program to protect fruit and foliage during the period of activity of the adult flies.

In determining results McIntosh was the variety checked, since this was common to all the orchards. In the ten orchards where the program was carried out in full, maggot infestation in fruit scored was less than 1 per cent. Records of infestation in some of these orchards in 1929 showed the following comparison:

Orchard No.	Percentage of Maggot Infestation 1929	1930
1	25	0
2	90	.8
3	26 (Baldwins 40)	.3
4	Destroyed practically entire crop because of maggot infestation	.1

Supplementary observations on other varieties supported the results noted on McIntosh. The Cortlands in one orchard in 1929 were so badly riddled by maggot that the grower trucked the entire crop to the cider mill. In 1930 this variety showed but 2 per cent infestation.

Orchard surveys conducted by state and county agencies showed that apple maggot was present in considerable abundance throughout the State in 1930. In one instance an infestation of 78 per cent was noted, and in several orchards fruit showed 30-40 per cent damage. In very many cases an infestation of 10-15 per cent was noted. The results secured in the test orchards, therefore, would not appear to be attributable to any scarcity of the pest this past season.

In addition to checking apple maggot, the spray program in the test orchards enabled the growers to control many other pests and made it possible for them to harvest better quality fruit. Five of the ten growers produced McIntosh, 90-95 per cent of which was free from insect or disease blemishes. In three other orchards the fruit scored 80-85 per cent clean. The improvement made by these growers in the quality of the fruit produced is indicated by the following examples:

Orchard No.	Percentage of Crop Clean 1929	1930
1	1.6	51
2	10	83
3	40	82
4	Less than 10	95

One of the most encouraging features of the campaign was the fact that the late sprays or dusts recommended for control of the apple maggot gave such excellent protection against other pests as well that their use was justified aside from the question of maggot control.

DEPARTMENT OF FARM MANAGEMENT

J. A. Foord in Charge

Enterprise Relationships and Farm Organization on Selected Dairy Farms in Western Massachusetts. (R. L. Mighell). The work on this project has been somewhat more specialized than last year. Simple financial records have been continued by the owners of the farms used in the project. A more detailed study of several of the farms, based on the records already obtained, has been made by the investigator and some suggested changes in organization have been adopted. Time studies of several farm operations have already been made and more are in progress.

Types of Farming in Vegetable Garden Areas. (F. H. Branch and R. L. Mighell). This project was begun as a part of the extension work of the department, but owing to the demand for information, it seemed wise to make it one of the major projects for investigation. The Extension Service contributed funds for obtaining the data in the field; and the work was done during the summer. More than a hundred growers in the counties of Bristol, Essex and Middlesex were visited, and 320 enterprise records obtained. The tabulation and study of this material revealed important differences and several special types of organization.

The material will be available for Extension Service use this winter and also serve as a basis for investigations in these areas in the future.

Live Stock Management, Methods and Costs. (J. A. Foord). Data are being accumulated on the methods and expense of eliminating Bangs Disease in herds, as well as the advantages and labor involved in different methods of housing and handling dairy cattle.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, H. R. DeRose, A. F. Spelman, G. J. Larsinos, J. B. Zielinski, Jr.[1], J. W. Kuzmeski[2], F. A. McLaughlin, J. T. Howard). During the fiscal year, 1,738 samples of feeding stuffs officially collected were examined in the control laboratories. The results show that at least 96 per cent of the samples collected varied less than one per cent from stated guarantees in protein, fat and fiber content. The gross receipts from the registration of feeding stuffs in 1930 (calendar year) were $21,000, derived from 1,050 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, O. W. Kelly[3], Elizabeth F. Hopkins[4], Margaret E. Nagle). From October 1, 1929, to October 1, 1930, the seed laboratory analyzed 854 seed samples, 349 of which were collected by the State Commissioner of Agriculture, 390 sent in by dealers and farmers, and 115 from the Rhode Island State Commissioner of Agriculture. Classification of these analyses is shown by the following summary.

Summary of Samples Analyzed

	Rhode Island	Non-Official	Official	Total
Purity only	20	18	18	56
Germination only	4	235	216	455
Purity and Germination	91	137	115	343
				854
Field Crops	7	120	18	145
Forage	104	103	115	322
Vegetables	4	158	216	378
Tree		9		9
				854

Field tests to determine trueness to type were again conducted in co-operation with the Department of Agronomy which tested 16 samples of red clover, 4 of sweet clover and 11 of alfalfa, and the Department of Vegetable Gardening which tested 132 varieties and strains of varieties of onions.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen). During the year ending December 1, 1930, 8,871 pieces of Babcock glassware were tested, an increase of 356 over 1929. Condemned glassware consisted of 13 milk pipettes, which were not condemned on account of inaccuracy of graduation but because they did not meet with accepted standards; the graduation mark was so near the suction end of the pipette as to render pipetting difficult. Ninety-four certificates of proficiency were awarded.

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[1] Resigned Oct. 1, 1930.
[2] Resigned Jan. 1, 1930.
[3] Resigned June 1, 1930.
[4] Temporary appointment for month of July.

One hundred and sixty creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, three machines were condemned outright, major repairs were ordered on five, and minor on twelve. In eighteen places new glassware was ordered, and at four, operators were cautioned on account of improperly cleaned glassware. Twenty-seven places were ordered to keep composite samples in better condition. Where it is thought necessary, re-inspections will be made. At the request of interested individuals, special investigations were also made at four different plants.

Advanced Registry Testing. (P. H. Smith). Advanced registry testing has been supervised by this department since its beginning in 1902. This work has been carried on for so long that there is no material growth in it from year to year. The work at this time (November 1929) is of practically the same volume as it was a year earlier. There are now on yearly test 602 cows located on 77 different farms. This does not include the herd tests where all animals in each herd are placed on test. Of these there are eighteen, six of which are supervised by men sent out from this office and twelve by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, J. W. Kuzmeski, J. B. Zielinski, Jr., A. F. Spelman, G. J. Larsinos). Numerous analyses have been made for residents of the State and other departments of the College. Especial attention is called to the increasing number of dry matter determinations in connection with forage crop experiments. This work has become a real burden upon other work of the department and should it increase materially, the employment of an additional assistant during the summer months will be necessary.

Summary of Miscellaneous Work, 1930

Materials sent in:	
Milk and cream, butterfat only	388
Milk, solids and fat	28
Feeds	66
For other departments of Experiment Station and College:	
Milk, for butterfat	200
Dry matter, forage crops	1,324
Complete fodder analyses	177
Dry matter and nitrogen	127

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. B. Zielinski, Jr., and G. J. Larsinos). During the season, 135 firms or individuals have registered for sale in Massachusetts 598 brands of mixed fertilizers and unmixed fertilizing materials and 26 brands of agricultural lime and gypsum. The nature of these materials, as well as statistics with reference to the inspection, is given in the following summary.

Products	Brands Registered	Brands Collected	Samples Collected	Number of Analyses	Number of Determinations*
Mixed fertilizers	361	338	1153	394	5122
Ground bone, tankage and fish	59	51	134	60	316
Nitrogen products, organic and mineral	76	64	240	149	330
Phosphoric acid products	30	28	100	31	155
Potash products	34	30	69	39	149
Dried, pulverized natural manures	21	21	80	23	115
Miscellaneous	10	8	16	14	71
Lime products	26	26	41	29	145
Nitrate of potash	6	5	11	7	28
Ammonium phosphate	2	2	5	4	24
Totals	625	573	1849	750	6455

* Not counting check tests or repeats, which would probably amount to one-third more in number.

The four men employed to secure samples for the year's inspection sampled 19,631 sacks or containers, representing 5,875 tons of material: 912 agents were visited.

From July 1, 1929, to July 1, 1930, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons) Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	42,881	1,791	3,366	2,703
Unmixed fertilizer chemicals and materials	21,249	1,441	1,636	584
Pulverized natural manures	2,491	56	37	77
Totals	66,621	3,294	5,039	3,364

Full details of the fertilizer and lime inspection will be found in Bulletins 54 and 57, Control Series.

Miscellaneous Analytical Work. (H. D. Haskins, H. R. DeRose, J. B. Zielinski, Jr., and G. J. Larsinos). As usual, the last two months of the year and the first three months of the new year, much cooperative chemical work was carried on with other departments of the Experiment Station. The general nature and extent of this work may be seen from the following summary:

Cured tobacco, complete ash analysis	16
Complete fertilizer	1
Dwarf Essex rape plants, dry matter and phosphoric acid	81
Fertilizer chemicals and unmixed materials	3
Japanese millet plants, dry matter and nitrogen	101
Onions, partial ash analysis	1
Organic ammoniates, complete analysis including nitrogen activity	25
Phosphates, complete analysis for vegetation test	18
Soil analysis, partial chemical	29
Soil mechanical analysis	7
Tobacco plants, partial analysis	21

The fertilizer department has also been active in assisting the citizens of the State, through farm organizations, institutional departments, and in

personal contact with the individual, in the analysis of a variety of materials of interest to agriculture. Where the results of the work are of principal interest to the individual a nominal charge has been made as in the past. Interpretations and advice accompany the report of analysis in all cases. The following materials have been analyzed under this heading:

Complete fertilizers	11
Fertilizer chemicals and unmixed materials	73
Fish, tankage and bone	5
Lime products	1
Insecticides	1
Manures	3
Manufacturers' by-products, for fertilizer value	3
Miscellaneous	2
Peat products	15
Soils, complete chemical analysis	7
Soils, partial chemical analysis	12
Soils, mechanical analysis	10
Wood and cotton hull ashes	14

In addition, the usual amount of cooperative work has been done for the Association of Official Agricultural Chemists, consisting of analytical work for the Referee on Nitrogen, and service on the Committee on Definition of Terms and Interpretation of Results on Fertilizers and Lime Products.

Vegetation Pot Experiments. (H. D. Haskins, G. J. Larsinos and H. R DeRose). An experiment comprising 79 pots in a study of phosphoric acid availability of 18 phosphates was begun. It is hoped that the experiment may be continued for two years more before final conclusions are drawn. A vegetation experiment was also conducted in further study of the nitrogen availability of processed low-grade organic substances, oil-extracted seed residues and other organic nitrogenous materials which are largely used in mixed commercial fertilizers. Pots were also included to note the effect of manganese sulfate. Detailed results of these experiments are reported in Control Bulletin 54.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Study of the Effect of Plant Nutrients on Carnations and Roses Under Glass. (H. E. White, Waltham). This project was started in June, 1930, with the aim of studying the effect of the sources of nitrogen and phosphorus (organic and inorganic) on growth and flower production. Fifteen plots of thirty-five plants each of carnations, triplicated, and fifteen plots of twenty-four plants each of roses, duplicated, were established; fifteen fertilizer treatments are being used.

Since the first heavy crop of carnations is just coming into bloom, it is not possible to present data on flower production. The plots receiving the following treatments have produced taller and heavier plants:—manure and superphosphate, manure and peat, superphosphate and peat. There

does not appear to be any visible difference between the remaining plots.

The rose plots which received manure and peat, superphosphate and peat, and manure and superphosphate have produced stronger plants and have given a few more blooms per plant during the month of November.

Definite conclusions cannot yet be drawn from the experiments, since the work has been in progress for a comparatively short time.

The following table shows the various plot treatments.

Plot No.	Treatment
1	Superphosphate Manure
2	Manure Peat
3	Superphosphate Peat
4	Nitrate of Soda Superphosphate Muriate of Potash
5	Nitrate of Soda Superphosphate Muriate of Potash
6	Guano Superphosphate Muriate of Potash
7	Fish Superphosphate Muriate of Potash
8	Fish Bone Muriate of Potash
9	Nitrate of Soda Bone Muriate of Potash
10	Urea Superphosphate Muriate of Potash
11	Calurea Superphosphate Muriate of Potash
12	Blood Superphosphate Muriate of Potash
13	Nitrate of Soda Basic Slag Muriate of Potash
14	Nitrate of Soda Superphosphate Muriate of Potash
15	Nitrate of Soda Basic Slag Muriate of Potash Swamp Peat 2:1

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (H. E. White, Waltham). The work on the development of rust-resistant varieties of snapdragons for commercial use was started in June, 1930. Twelve rust-resistant strains, obtained from the Purdue University Agricultural Experiment Station, were planted in the field among ten garden varieties. By August 12 the garden varieties were destroyed by rust, whereas seven of the twelve resistant strains produced thirty plants that were entirely free from the disease. Since these strains do not possess flower color and length of stem desirable in commercial varieties, it will be necessary to breed plants having the desired commercial qualities and the rust-resistant characters. Breeding work was not done in the field due to the hot, dry weather conditions at the time the plants were in bloom. The resistant strains are now being grown in the greenhouse and will be crossed with commercial varieties during the winter and spring.

DEPARTMENT OF HOME ECONOMICS RESEARCH

Esther Davies in Charge

Present Practices of Massachusetts Elementary Schools with Regard to School Feeding and Transportation and Their Effects upon Health of Pupils. (E. Davies). The section of this project dealing with food service has been entirely completed and a bulletin published describing the

methods used in the study and the results obtained. (Bulletin No. 263; April, 1930).

The field work for the study of transportation of pupils to rural elementary schools has been finished and the data are in process of tabulation. The study includes consideration of methods of awarding transportation contracts, requirements as to type and condition of vehicles, behavior of drivers, planning of routes, length of time transported pupils are away from home, and the relation of transportation to school absences and various pupil illnesses. In most of the rural Massachusetts towns, the entire problem of transportation is settled on the basis of financial economy, the other factors being unregarded; while the experience of a few towns shows that transportation can, if sufficient thought is given to the matter, be so arranged that the health of the pupils is not adversely affected and, at the same time, costs be kept within reasonable bounds.

The Comparative Values of Milk and Tomato as Supplementary Feeding in a Rural Elementary School. (E. Davies and M. V. E. Voorneveld). After one year of experimental feeding in a rural school in the eastern part of the State, the study is being continued for a second year in a consolidated school of similar size and racial composition, in the Berkshires. The data cannot be tabulated until the end of the second year of experimentation, and it is not now possible to reach any conclusions as to the comparative value of the food stuffs studied.

The Value of Evaporated Milk for School Food Service. (E. Davies and O. A. Merriam). This project is similar in purpose and method to that concerned with fresh milk and tomato as materials for supplementary food service in schools. The experimental work is to continue for two years, and is being carried on in a village having a very large proportion of children of foreign-born parentage enrolled in the schools. No information regarding the outcome of the experimental work is available at the present time.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Extraction of Fruit Juices by Heat. (C. R. Fellers). This project has now been completed and the results are being prepared for publication. Optimum extraction methods for jelly manufacture are outlined. A new rapid centrifugal method for the determination of pectin in fruit juices has been developed which is sufficiently accurate for ordinary work.

Concentrated pectin extracts made from cull apples or thinnings, are readily prepared, inexpensive, and, when freshly prepared, suitable for use in jelly making. However, after a few months' storage precipitation occurs, and the pectin loses much of its jellifying properties. Homemade pectin extracts should, therefore, be used while fresh.

A number of commercial benzoate cider preservatives were examined for suitability for use in freshly prepared cider and grape juice. Great differences were noted. In general, too much benzoate is added to cider, from .05-.06 per cent being sufficient if the cider is fresh and reasonably free from sediment. The sharp taste of benzoated cider is due largely to chlorine impurities in the preservative.

Several types of equipment designed to determine the jelly strength of jellies have been compared. Work is being done on the development of a new jelly tester similar in construction to the Magness fruit pressure tester.

Manufacture and Preservation of Cranberry Products. (C. R. Fellers, J. A. Clague, and W. W. Chenoweth). Close cooperation with the American Cranberry Exchange and the commercial cranberry preservers has been maintained. The use of the Abbé refractometer for determining the proper finishing point in cranberry sauce manufacture has been introduced into all of the commercial canneries. By this means the quality of the sauce is maintained and every batch can be standardized to a definite sugar content (42-44 per cent), insuring also maximum yields consistent with optimum jelly strength.

Frozen cranberries held at 10° F. for 1 to 12 months were found to be very satisfactory for sauce manufacture, the sauce retaining all the flavor, color and jelly strength of the fresh-fruit sauce. This year some of the canners are freezing several thousand barrels for manufacture during the off season.

Canned cranberry sauce was shown to be impaired by freezing. The jelly strength was decreased as much as 20 per cent and syneresis (bleeding) was greatly increased.

Researches are under way in cooperation with the State Cranberry Station on the suitability of about 30 commercial varieties for canning purposes. Strained and whole sauce is manufactured from each variety, the yield, characteristics and keeping qualities being noted.

The American Cranberry Exchange of New York, through a grant of $1000, requested the department to carry on nutritional studies on the cranberry. The first research attempted was a determination of the vitamin C content of raw cranberries and fresh and canned cranberry sauce. Preliminary results on 45 guinea pigs indicate that the raw cranberries contain substantial amounts of vitamin C, but practically all is destroyed by the manufacturing process. This work is being actively continued in order to evolve, if possible, a method of sauce manufacture which will protect the vitamin C. Cranberry juice is also a rich source of vitamin C, as little as 3 cc. per day protecting guinea pigs against scurvy for at least 90 days. The use of cranberry juice as a beverage is also being investigated.

Utilization of Onions by Canning. (C. R. Fellers). The examination of experimental packs of canned onions made in 1929 and 1930 fully bear out earlier conclusions as to the feasibility of canning onions in tin cans or glass jars. Chemical studies on canned onion discoloration are being conducted by the Chemistry Department. Continued tests on dehydrated cull onions and the ease of manufacture of onion powder or "flavor" have renewed confidence in the feasibility of utilizing cull onions in this way. Preliminary experiments on preserving small onions in brine for pickling purposes indicate that a 60 degree salometer brine is preferable to lighter brines.

Nitrogen Distribution of the Edible Portion of the Onion. (F. P. Griffiths). This project was discontinued upon the resignation of Mr. Griffiths on July 1, 1930. Nitrogen in the form of ammonia, nitrate, amino acids and protein was determined in fresh and dried onions.

Utilization of Frozen Fruits in Ice Cream. (C. R. Fellers and M. J. Mack, Dairy Department). This cooperative project has been continued for the third year, utilizing various varieties of strawberries, raspberries, cherries and peaches. For the first time fruits were packed with different syrup concentrations in place of solid sugar. Results to date indicate marked superiority of the sugar syrup packs of fruit. Oxidation, discoloration and mushiness are largely obviated by the use of 40 to 60 per cent sugar syrups. Invert syrup gave no better results than sucrose syrup. Corn sugar was distinctly unsatisfactory. Berries and cherries were frozen with solid sugar and with syrup in gallon cans under vacuum. These packs, though more costly to put up, gave the best quality of fruit. Hawaiian pineapples were superior to Porto Rican varieties for ice cream making. Preliminary work was done during the summer on freezing various vegetables.

Pasteurization of Dried Fruits. (C. R. Fellers and J. A. Clague). Further results have definitely proved that such dried fruits as dates, figs, and raisins may be effectively pasteurized and freed from insects and pathogenic bacteria by a heat treatment under standardized time-temperature-humidity relationships. This work has now been discontinued, the results being published in *American Journal of Public Health* Vol. 20, 175-181 (Feb. 1930) and *Journal of Bacteriology* Vol. 21, No. 1 (Jan. 1931).

Chemical Composition of Dates. (M. M. Cleveland). The Hills Brothers Company Research Fellow for 1931-32 is making a study of the organic and mineral constituents of dates, with special reference to nutritive properties. Possible uses for cull dates and date syrup are also included in this project.

Preservation of Rodent Bait. (In cooperation with U. S. Bureau of Biological Survey). Experiments have been conducted on the feasibility of preserving rodent baits containing red squill. If the canned product proves satisfactory, the use of poisoned meat, fish and cereals by farmers and others will be greatly facilitated.

DEPARTMENT OF HORTICULTURE

Frank A. Waugh in Charge

Turf Management. (L. S. Dickinson). The results of past studies of the appearance and control of the large brown patch disease (*Rhizoctonia solani*) were published in *Phytopathology* for August, 1930, under the title "The effect of air temperature on the pathogenicity of *Rhizoctonia solani* parasitizing grasses on putting green turf." Field observations again verified the results obtained in previous years, and each attack of the disease was accurately forecast during the 1930 season.

Further progress has been made in the use of fertilizers to maintain healthy turf during periods of extreme drought, especially where artificial watering is impractical. It appears that certain combinations of fertilizers can offset to a considerable degree the disadvantages of a dry season and produce excellent turf.

Studies in the control of mouse-ear chickweed (*Cerastium vulgatum*) and

pearlwort (*Sagina procumbens*) have been started and should prove of value to growers of fine turf.

The series of plots established in cooperation with the United States Golf Association is furnishing data particularly valuable to golf-course management and of equal use to cemetery and park superintendents. The soil of the plots is of clay loam, thus furnishing unusual opportunities for observations concerning earthworms and the growth of grass as affected by the compactness of the soil. These plots are also giving information regarding the effect of fertilizers on weed invasion.

Several additional species of grasses have been placed in the trial plots.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY

J. B. Lindsey in Charge

The Effect of Fertilizer and Cultural Treatment on the Nitrogenous Compounds of Havana Seed Leaf. (E. B. Holland and E. Bennett). Analytical work on the several grades of Havana tobacco grown on the experiment station plots under different fertilization and cultural treatment has been continued. The plants were harvested at different stages of growth, cured on the stalk, stripped and sorted. After the midrib and several coarse laterals had been removed, the residual web was ground and analyzed, with attention directed largely to the nitrogenous compounds. In many instances the number of replications was insufficient to establish a positive trend. Furthermore, seasonal variations in growth and curing and possible differences in drawing and sorting small samples have to be considered. The following deductions seem warranted.

(1) The percentage of total, soluble, and amido nitrogen increased in the several grades from the base of the plant upwards; the nicotine increased from the base of the stalk to the light or medium wrappers, and the acid soluble and insoluble ash decreased.

(2) Low topping increased the percentage of total nitrogen, soluble nitrogen, nicotine and acidity in seconds and reduced the acid soluble and insoluble ash.

(3) The percentage of total, soluble, and ammoniacal nitrogen, acid soluble ash and acidity decreased with maturity in seconds and darks, while nicotine and insoluble ash increased.

(4) An increase in applied nitrogen increased total nitrogen, soluble nitrogen and acid soluble ash within narrow limits, but as a whole affected the yield and size of leaf rather than composition.

(5) Nitrate of soda and sulfate of ammonia increased the total nitrogen in seconds more than the regular tobacco fertilizer mixture or cottonseed meal. Nitrate nitrogen and nicotine were low on cottonseed meal. Sulfate of ammonia increased acidity as would be expected, and nitrate of soda gave the least acidity.

(6) Timothy in the rotation increased the percentage of soluble nitrogen, ammoniacal nitrogen, nicotine and acidity and reduced the percentage of acid soluble ash.

(7) Continuous tobacco gave a slightly higher percentage of total, soluble, and ammoniacal nitrogen, acid soluble ash and higher pH than tobacco following onions or potatoes.

In addition to the chemical studies here reported, the yield, grades, and market value of Havana tobacco grown on the experiment station plots under different fertilization and cultural conditions have been compiled.

Oil Sprays. (E. B. Holland). The preparation of numerous miscible oils and stock emulsions with diamond paraffin oil (a light lubricating oil) and different emulsifiers has been continued and the stability against stratifying and breaking on test noted. The work is time consuming as it is largely on a trial and error basis[1]. As a whole the miscible oils prepared by spontaneous methods are the most promising, easy to make, and relatively inexpensive. The laboratory samples applied last spring gave satisfactory results in the field.

The work should be continued with a medium paraffin oil.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-Legumes under Certain Defined Agronomic Conditions. (F. W. Morse). This year (1930) all the plots were seeded with Japanese millet. Conditions were favorable for uniform growth until July 22, when a short, severe thunderstorm beat down the millet on the plots fertilized with nitrogen, which inhibited subsequent growth up to the date of cutting (August 19) and also caused a heavier stubble to be left on the field.

A comparison of the annual production with and without nitrogen for both systems of cropping is presented for this and the preceding years. The plots selected for comparison are adjacent to each other; Plot 9 which has not received nitrogen since 1882 and Plot 10 which has received organic nitrogen throughout the period. During this study the applications of nitrogen have been made in alternate years, 1924, 1926, 1928, and 1930. Plot 10 received a total of 80.9 kilograms of nitrogen per acre in the form of dry ground fish.

Scanning the results with leguminous crops used in rotation, it will be noted that clover did not respond to the use of nitrogen in the fertilizer whether applied directly as in 1924 or the previous year as in 1929. Soy beans, however, did respond to the direct application of nitrogen in 1926, especially in the amount of nitrogen recovered in the crop. Corn was grown in the years when nitrogen was withheld, but showed some gain due to the previous season's application. Millet in 1930 received a direct treatment with nitrogen and responded, especially in the yield of nitrogen in the crop.

The results with continuous non-leguminous crops show very plainly their response to applications of nitrogen in the fertilizer.

The objective of the experiment, however, was to ascertain whether or not there was fixation of nitrogen in the soil in the absence of leguminous plants. It will be noted that as the years have passed the three kinds of crops, grass, corn, and Japanese millet, without nitrogen, have gained in production of dry matter and yield of nitrogen instead of decreasing as one might expect if no nitrogen was being fixed.

Similar comparative results were obtained with adjoining plots, No. 7

[1] Some ratios seem to indicate that there may be a fundamental reaction involved.

without nitrogen and No. 8 which received 80.9 kilograms of nitrogen per acre in sulfate of ammonia.

It is planned to continue the investigation.

LEGUMINOUS CROPS GROWN IN ROTATION

(Kilograms of Dry Matter and Nitrogen removed per Acre)

Year	Crop	Without Nitrogen		With Nitrogen	
		Dry Matter	Nitrogen	Dry Matter	Nitrogen
1924	Clover	1866	49.8	1792	46.5
1925	Corn	1766	29.8	1816	31.3
1926	Soy Beans	1596	39.9	1860	50.0
1927	Corn	1164	18.5	1310	23.0
1928	Clover and Weeds	1334	18.9	1340	17.1
1929	Clover	1852	41.9	1714	37.9
1930	Millet	2575	32.7	3011	43.2
	Total	12153	231.5	12843	249.0
	NON-LEGUMINOUS CROPS GROWN CONTINUOUSLY				
1924	Grasses	496	4.6	1393	10.1
1925	Corn	1010	13.1	1280	18.5
1926	Millet	2126	14.0	4286	36.5
1927	Corn	1294	21.5	1258	22.8
1928	Grasses and Weeds	1478	13.2	1846	17.9
1929	Grasses	617	6.0	1055	10.8
1930	Millet	3066	29.3	2984	40.6
	Total	10087	101.7	14102	157.2

Chemical Study of Cranberries. (F. W. Morse). The work of the last four years has been issued in Bulletin No. 265, "A Chemical Study of Cranberries".

Milk Substitutes in the Growing of Young Calves. (J. B. Lindsey and J. G. Archibald). For a part of the year 1929 and during 1930 studies have been in progress of a system based largely upon dry feeding, no liquid except water being fed after the first few weeks.

The first group of nine high-grade Holstein calves, five bulls and four heifers, was fed on the so-called New Jersey ration consisting of whole milk for three weeks, decreasing the same during the fourth week so that at the beginning of the fifth week the calves were receiving only dry feed, consisting of alfalfa for roughage and a grain mixture containing some 12½ per cent of soluble blood flour. The calves did fairly well and averaged 231 pounds (200-287) in weight at four months of age, making an average daily gain of 1.15 pounds.

A second group of five calves, three bulls and two heifers, was fed in the same way, except that rowen was fed in place of alfalfa. They averaged 228 pounds (210-238) in weight at four months of age, with an average daily gain of 1.12 pounds.

A third test is now in progress in which white fish meal was substituted for the blood flour. The calves did not take to the grain ration as readily because of the odor of the fish meal. Three records have been completed and two others are in progress. The three completed records show an average weight of 227 pounds at four months of age and an average daily gain of 1.02 pounds.

While it is possible to grow Holstein calves by the dry method of feeding, it is not to be commended. Most of the calves appeared thin, "pot bellied," and not in as satisfactory condition as those receiving a portion

of natural skim milk or diluted skim milk powder until four months old. It is believed that very young calves should be given a vigorous start by feeding some form of milk as a part of the ration until they are at least four months of age. (See Bulletin 253 of this Station). They should not be converted into cud chewers too early.

Mineral Requirements for the Growth of Dairy Heifers. (J. B. Lindsey and J. G. Archibald). A study of the calcium requirements has been completed, using eight high-grade Holstein heifers. They were divided into two groups; one was fed a ration high in calcium while the ration for the other group was low in calcium. The average age of the heifers was 140 days at the beginning and 858 days at the end of the experiment, or time of calving. The ration for the high-calcium group consisted largely of alfalfa hay, together with dried beet pulp and a grain ration made up mostly of corn meal; for the low-calcium group hay of mixed grasses (with 30 per cent alfalfa during the first period), dried apple pomace, and corn and linseed meals. Seventy-six satisfactory metabolism balance trials were completed. The detailed data and discussion of results have been prepared for publication and sent to the *Journal of Agricultural Research.*

The results, as a whole, point to accumulation of a considerable reserve of all elements by the high-calcium group during the first year and a lowering of retention later on. The low-calcium group, on the other hand, not having accumulated such a large reserve in the earlier stages, must have felt the need of more calcium and made the effort to utilize it to a greater degree in the third year.

BALANCE RECORD OF RETENTION FOR EACH GROUP DURING THE ENTIRE EXPERIMENT

	Daily retention		Daily retention per 100 lbs. live weight		Retention percentage of intake	
	High calcium group	Low calcium group	High calcium group	Low calcium group	High calcium group	Low calcium group
	Grams	*Grams*	*Grams*	*Grams*	*Per cent*	*Per cent*
Nitrogen	25.49	18.73	3.49	2.88	21.12	18.20
Calcium	7.74	4.45	1.06	0.68	17.76	21.60
Phosphorus	3.52	2.15	0.48	0.33	27.36	14.83
Magnesium	0.22	—0.48	0.03	—0.07	1.42	—3.18

The establishment of approximately a 2 to 1 ratio between the amounts of calcium and phosphorus retained, irrespective of the ratio in the intake, was very uniform in both groups and at all ages.

The records of weight and height at withers did not show that one group made any better growth than the other, in spite of the larger assimilation of the elements by the high-calcium group. On the basis of the results secured, it would seem to be a reasonable conclusion that heifers can make satisfactory growth on rations supplying approximately 4.5 grams of calcium daily during the first year of life, 3 grams daily during the second year, and 2.5 grams daily during the third year, for each 100 pounds of live weight. A good quality of hay with 30 per cent of legume hay or rowen during the first year will supply these amounts, while legume hay for roughage will be necessary to supply such amounts as were retained by the high-calcium group.

Two Systems of Dairy Cattle Feeding—High Roughage and Low Grain versus Low Roughage and High Grain. (J. B. Lindsey and J. G. Archibald). This project was organized and started in the autumn of 1928 and is intended to continue for at least three years. The object has been to make careful observations, under controlled conditions, of the effect of maximum roughage and low grain (1 pound to 4½ pounds milk) fed to one group of cows, and minimum roughage and high grain 1 pound to 2½ pounds milk) fed to another group, upon the economy of milk production and the condition of the cows as regards appearance, live weight, and breeding. The roughage has consisted of first cut hay, rowen, silage, and green forage fed in different amounts; and the grain, of a mixture of wheat bran, ground oats, corn meal, gluten feed, and cottonseed meal, mixed in different proportions for the two groups.

The results for the first year ending in October, 1929, showed very little difference between the two groups. At this writing, data for the year ending October, 1930, have not been completed.

The Chemical Composition of Grass from Plots Fertilized and Grazed Intensively. (J. G. Archibald). Results for 1929 have been published in the *Journal of Agricultural Research*, Vol. 41, No. 6, for September 15, 1930.

The fertilizer treatment decreased considerably the dry matter content of the grass and the crude fiber content of the dry matter. All other constituents of the dry matter that were determined were increased, the nitrogen showing the most significant rise. Acre production or recovery of all constituents was increased, nitrogen being nearly double that recovered on the check plot. The effect of withholding nitrogen from one plot was very marked.

The conclusions reached in the earlier publication (see Annual Report for 1929) regarding (1) increase in nutritive value due to fertilization, (2) absence of any appreciable effect of the treatment in leveling seasonal fluctuations, and (3) changes in chemical composition of the grass as the season advanced are substantiated and strengthened by the results of 1929.

A careful study of all results for both seasons (1928 and 1929) and correlation of these with the weather records leads to the further conclusion that of all the factors influencing the chemical composition of grass, producing as they do marked seasonal fluctuations, the amount of rainfall is the most important.

The study has been continued during 1930, but results are not yet available. It is planned to bring this phase of pasture grass studies to a conclusion with the publication of the present season's results.

As an outgrowth of the above study and in response to a demand for more fundamental information on pasture problems, a more complete project entitled "Studies in the Chemistry of Pasture Grass" was organized early in the year. The objective in this project is to ascertain the fundamental chemical facts which agronomists and animal husbandmen need as a basis from which to start in their study of the agronomic and nutritional phases of the problem, and upon which to base recommendations in practice.

In connection with this work 154 samples of pasture grass have been collected during the past season, and analytical work at date of writing (December 16, 1930) is about half completed.

DEPARTMENT OF POMOLOGY

F. C. Sears in charge

The yield of apples and peaches from the station orchards in 1930 was by far the largest in recent years. The quality was also good. Bloom was heavier than usual, and the crop harvested was more than twice that of last year.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw and J. S. Bailey). The usual observations of growth, bloom and yield have been continued. In some parts of the orchard the trees are crowding each other, and a general thinning out of the orchard is necessary. The results of this work suggest that root influence is more likely to dwarf a variety than to invigorate it. The results from the main orchard have been summarized and will soon be prepared for publication.

The young orchard of McIntosh and Wealthy set in 1928 has made a good growth and shows that the East Malling Stocks have a strong influence on growth. The trees are much dwarfed by stocks 8 and 9, while 12 and 16 have thus far developed trees equal in vigor to budded or own-rooted trees. The two varieties are influenced about alike except that there is a striking difference when propagated on stock No. 1, which dwarfs the Wealthy distinctly while McIntosh makes a fairly vigorous tree.

Root cuttings from five-year-old Malling Stocks gave poor results, while scions grafted on nurse roots started well, as did rooted layers. An effort is being made to increase the supply of these Malling Stocks.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French). Work on this project has continued both in Amherst and in various nurseries. A nursery containing nearly 150 varieties of apples, including all varieties commonly grown by nurserymen, has been established. Detailed observations and photographic records will be made. The leaders of this project have continued the work of certifying varieties in certain nurseries for several years. Recently the practice of examining all trees when one year old has become established. Thus the propagation of mixtures is avoided and the stock in these nurseries is now almost free from misnamed trees.

The Genetic Composition of Peaches. (J. S. Bailey). No additional crossing work was done in 1930. Of the 1260 seedling trees from previous work in the orchard, 717 fruited for the first time. Of those fruiting, 289 seedlings are crosses and 428 selfed. The fruits of 275 seedlings are white fleshed and of 442 yellow fleshed; 119 are clingstones, 22 semi-cling, and 576 freestones. Fifty-three seedlings are considered worthy of further observation. Yield was better in the higher parts of the orchard where more fruit buds survived the winter. Hence yield was more dependent on hardiness and location in the orchard than on inherited ability to form fruit buds.

Although one year's results are not enough to draw conclusions from, yet certain statements can be made when the results check with the work of other investigators. The reniform type of foliar glands is dominant, glandular is recessive, and globose is intermediate. White flesh color is dominant, and yellow recessive. Belle is a heterozygous white. Hale,

Chile, Gold Drop, Crosby, Fitzgerald, and Elberta seem to be fairly homozygous for ripening date, while Belle and Champion are heterozygous. Vainqueur, Greensboro, and Carmen seem to transmit earliness in crosses. A character for very tough flesh appeared in the selfed progeny of Champion and Belle. It appears to be recessive.

The work with the freezing apparatus was continued. Not enough data have been obtained to draw conclusions, but length of exposure to cold and previous exposure to high or low temperatures seem to be important factors in influencing the killing temperature, as well as rate of temperature fall. Lowering the temperature to near the killing temperature and then holding it there for twenty-four hours offers some promise as a method for determining the relative hardiness of varieties and seedlings.

Testing Methods of Pruning. (J. K. Shaw). The project with young bearing trees has been carried on as before. The weights of prunings and growth, bloom and yield were recorded. No new or striking results have appeared, and at present it seems that this experiment suggests lessened rather than increased importance of pruning. While the pruning of bearing apple trees will doubtless be continued, its effect on the crop is probably far less than that of soil management or spraying.

Effect of Pruning on Bearing Apple Trees. (W. L. Cutler). This experiment on trees now forty years old is in its fourth year. No striking differences in size, color, or quality of the fruit have yet appeared. The evidence now available indicates that heavy pruning has, on the whole, decreased yields; and that light pruning may have given somewhat greater yields than no pruning.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw). This experiment has continued as in the past four years. The cultivated plots without fertilizer gave a fair crop of high color this year, yet much less than fertilized plots. The highest yield for the four-year period has been from the cultivated plot receiving nitrogen, but the color is not quite as high as that from the sod-nitrogen plot. There seems to be a benefit from the addition of potash to nitrogen on sod plots, but as this potash plot has always yielded more than the one without nitrogen a careful analysis of more data is needed before final conclusions may be drawn.

Comparison of Clover Sod and Grass in Sod Mulch Orchard. (J. K. Shaw). The white clover on the potash-phosphorus-lime plots continues to increase, but the yields of apples are still better on the nitrogen-phosphorus-potash plots. Determination of nitrates in soil from clover patches and from adjoining grass areas gave at no time higher nitrates in the clover. Growth and yield have been better on the clover plots than they were on nearby unfertilized sod plots.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw). The Baldwin trees in sod receiving 10, 17½ or 25 pounds of nitrate of soda gave a heavy crop this year. The color was inferior, but there was no difference between lots that had received different amounts. It is now planned to apply nitrogen in the non-bearing year only for a period of years to see whether color is improved and yields maintained.

Comparison of Cultivation and Heavy Mulching for Apples and Pears. (J. K. Shaw). The mulched plots continued to yield heavily, the McIntosh trees averaging nearly 30 bushels per tree while one tree yielded a total of 48 bushels. This comparison has continued for eight years and

seems to have demonstrated the superiority of heavy mulch over cultivation, both being without added fertilizer. It is planned to make some change in the test as it has been proved that a program of cultivation without fertilizer will not maintain production on this soil.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw). The fruit plants (apple, peach, grape, raspberry) that have been on this experimental field were removed in the spring of 1930. The fertilizer treatment was continued, and a crop of buckwheat grown and not removed. It is planned to reset the field in the spring of 1931 to own-rooted trees. These field plots with their long-continued fertilizer treatments serve as a source of soil for certain pot experiments.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw). A set of pot cultures similar to those of last year but with different fertilizer treatments were grown. Applied nitrates increased growth only to a small degree. Magnesium-free calcium carbonate was as effective without as with added magnesium sulfate. It seems clear that this soil having a pH value of about 4.75 is too acid for the best growth of fruit plants.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw). This project has been carried on without change. Determinations made at several times during the summer showed that soil nitrates were present on plots receiving no nitrogen-carrying fertilizer and also on some of the plots receiving nitrogen, though most such plots showed rather small concentrations at times. No nitrates were present on white clover areas on the phosphorus-potash-lime plot.

Study of Varieties of Tree Fruits. (J. K. Shaw and O. C. Roberts). The station continues to add new and promising varieties of fruits to its test orchards. All the more prominent "bud sports" of apples are under observation. There was an excellent crop on the new peach varieties received from the New Jersey Experiment Station. Most of these are promising and merit a trial by Massachusetts growers. There seem to be among them varieties that are worthy to replace most of the varieties now commonly grown with the exception of Elberta. The Ideal peach of New Zealand, received from the United States Department of Agriculture, gave a heavy crop of attractive peaches that seemed promising for home canning. The Newburgh raspberry, originated at the New York Experiment Station, gives promise of being a desirable mosaic-resistant variety. The Macoun apple seems to be a variety that should be tested generally in Massachusetts orchards.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter). This project was carried out as outlined in the last report and a new bed, with some modifications of treatment, set for fruiting in 1931. This bed includes fertilizer treatments as follows:

1. No nitrogen
2. August 15, nitrate of soda
3. August 15, sulfate of ammonia
4. August 15, urea
5. September 15, nitrate of soda
6. September 15, sulfate of ammonia
7. September 15, calurea
8. October 1, sulfate of ammonia
9. October 15, sulfate of ammonia

All plots are in quadruplicate and received applications of phosphorus and potash.

Three series have been added with treatments of phosphorus, phosphorus-potash and no fertilizer.

Bud Mutations Among Apples and Other Fruits. (B. D. Drain and W. H. Thies). A considerable number of selections from bud sport limbs and prospective mutation strains were made during the past year, and top grafted into trees of bearing age. These grafts grew nicely during the past season.

Light Pruning of Young Grape Vines. (B. D. Drain). The work of this project has been carried on for three years, with results similar to those reported in 1928. Leaf area measurements show a much larger leaf area on the light pruned vines.

Work not on a Project Basis. As in previous years considerable work, not formally organized on a project basis, has been carried on. This is either of a temporary nature or is preliminary to project organization. Some of it is carried on by members of the department not officially members of the Station Staff.

The "Set" of McIntosh Apples in Middlesex and Worcester Counties. This problem largely disappeared in the season of 1930 when most orchards set and matured good crops. It will doubtless return in later years, for the peculiarity of the variety will not change. Cooperative tests were carried out by some fourteen growers to learn something of the response of their orchards to certain treatments, mostly varying fertilizer and cultural treatments.

Blueberry Culture. (J. S. Bailey). For several years some work has been carried on with blueberries. This has been largely on propagation. One of the greatest difficulties in developing blueberry culture is the high cost of plants due to a lack of general knowledge of successful methods of propagation. Cuttings have been grown in ordinary cold frames and in a solar frame. Some progress has been made, and it is hoped that in the near future it will be possible to grow plants from cuttings with good success.

A Study of the Storage of McIntosh Under Various Conditions. (O. C. Roberts in cooperation with the Agricultural Engineering Department). This is the second year of this cooperative investigation of the most desirable storage conditions for McIntosh apples. Similar lots of McIntosh apples were stored at temperatures ranging from 45° F. to 32° F. After approximately two months, samples of each lot were transferred to 32° F. Periodical observations and tests were made to determine the condition of each lot.

The project has been extended to include a comparison of the blower type of refrigeration with the common direct expansion system with pipes extending along the walls. Samples of McIntosh apples were stored in various farm storages equipped with blowers, and duplicate lots were stored in the Nashoba cold storage at Ayer. Periodical observations were made and changes noted. Accurate data relative to the conditions in the various storage houses were also collected at frequent intervals.

Test of Spray Materials. (O. C. Roberts). Constant effort is being made by manufacturers and experiment stations to discover new materials and combinations which will enable the fruit grower to control the numer-

ous pests in his orchard without causing injury to the trees or fruit. In order that the effect of these materials may be determined for Massachusetts conditions, the Departments of Pomology and Entomology cooperating have made field tests of a few of those materials which have appeared to be of particular interest to Massachusetts fruit growers. Details of these tests are given in the report of the Department of Entomology.

Studies of Arsenical Residue on Apples. (O. C. Roberts). For the past four years a study of the amount of arsenical residue on apples as related to different spray schedules has been conducted by the Departments of Pomology and Entomology and the U. S. Food, Drug, and Insecticide Administration at Boston. This experiment is discussed in the report from the Entomology Department.

Cross-Pollination and Sterility Studies with Certain Apple Varieties. (F. C. Sears and O. C. Roberts). For the past six years the Pomology Department has been making a study of the effects of pollination on the set of fruit. Particular attention has been given to the McIntosh, the most important variety in Massachusetts. McIntosh is practically self-sterile, but appears to be a good pollenizer for other varieties. A few of the most reliable pollenizers for McIntosh are Wealthy, Delicious, Oldenburg, Ben Davis, and Cortland.

Pruning of Northern Spy Trees. (O. C. Roberts). In 1927 the trees in a small block of young Spy trees were divided into three groups. Each group has since been given different pruning treatments as follows: (1) Unpruned, (2) Heavy pruned, (3) Branches spread and lightly pruned. These trees have just begun to bear, so data on the effect of the various treatments on quantity and quality of fruit are as yet very limited. However, there seems to be an indication that the trees with branches spread and lightly pruned are more desirable than the others.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in charge

Broodiness in Poultry. (F. A. Hays). Progress is being made in establishing a non-broody and an intense broody line of Rhode Island Reds. A pen of 13 hens in the non-broody line ranging in age from two to five years was given access to open nests from April 20 to August 1, 1930, in studies on the effect of management upon broody behavior. Non-broody birds are being tested genetically for the complementary genes responsible for broodiness.

The intense broody line is being studied, with special reference to the inheritance of degrees of broodiness measured by number of broody periods. The non-broody and the intense broody lines are being developed with special reference to uniformity in other inherited characteristics, in order that the effects of broodiness may be accurately determined.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn). The mean annual production of the 352 birds hatched in 1928 was 221.4

eggs, an increase of about 16 eggs over any previous flock. This increase was brought about by superior intensity and greater persistency in the flock as a whole. Special attention is being given to improving egg size, reducing mortality rate, and eliminating winter pause. Mean egg size is improved, and the mortality rate for the 1928 flock for the full laying year was 14.85 per cent. Hatching records for the entire flock for the spring of 1929 show 77.7 per cent of fertile eggs hatched; for the spring of 1930 the figure was 74.5 per cent. These hatching records show progress, and include only eggs hatched under conditions used in pedigreeing.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn). Annual molt records from 1917 to 1928 were studied statistically and published in Bulletin 264. A paper on linkage relation for genes concerned in fecundity and genes concerned in egg size was prepared for the 4th World's Poultry Congress in London, July, 1930. Studies on time required for pullets to attain standard egg weight were reported at the 1930 Poultry Science meeting at Macdonald College.

A Genetic Study of Rhode Island Red Color. (F. A. Hays). In this experiment three strains are being developed: One is made up of pure Station stock selected for good color, a second consists of birds true to Standard from an outside source, and the third is made up of hybrids of the other two strains.

Determination of Genetic Laws Governing Results in Inbreeding Poultry. (F. A. Hays). Results of this project up to 1929 were reported in Bulletin 258. In the spring of 1929 the method of experimentation was changed somewhat in that the more rigid standards for selecting foundation breeding stock for high fecundity were employed. A new generation was established in 1929 in a special effort to avoid any inherited characteristics inimical to high fecundity. The second generation was produced in the spring of 1930 from half-brother and sister matings.

Heredity and Environmental Characteristics Affecting Variability in Egg Production. (F. A. Hays). The third generation of pullets in this experiment is now being tested for egg production. There are three rather distinct lines represented with respect to characteristics affecting fecundity. Data should be adequate for publication at the close of the laying year in 1931.

Factors Affecting Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays). Complete egg weight records from first pullet egg to January 1 are available on 2100 birds hatched in 1927, 1928, and 1929. Records on the weight of every egg laid by 500 females during their first laying year are also available. The third generation of birds in the small, medium and large egg groups was hatched in 1930. Sufficient data should be available for publication at the close of 1931. The application of methods already reported has produced improvement in egg size for the flock as a whole.

Relation of Intensity or Rate of Laying to Feather Pigmentation. (F A. Hays). Results of this project are being prepared for publication.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Elimination Law. (H. Van Roekel, K. L. Bullis, G. L. Dunlap, and O. S. Flint). The progress made in pullorum disease eradication during the 1929-1930 season is reported in Control Series Bulletin No. 53. Approximately one-seventh of the poultry population of Massachusetts was tested and the volume of work is steadily increasing. Compared with the previous season the following increases are noted:—48 tested flocks, 76,802 tested birds, 82,590 tests, 81 negative flocks, and 53 non-reacting 100 per cent tested flocks. Further comparison shows that the average percentage of infection was reduced from 4.25 to 2.35 per cent.

A study of 60 flocks tested for two consecutive years showed that intensive retesting or short-interval testing was more effective in eradicating the disease than annual testing. Similar results were obtained in 30 flocks tested for three consecutive years.

The relation of sexual maturity to pullorum disease eradication was studied in ten flocks which were subjected to the intensive testing plan. The results show that sexual maturity of pullets does not appear to play a role in eradicating the disease. From an eradication point of view, early pullet testing in infected flocks is more desirable than testing more mature birds.

Failure in eradicating the disease or in maintaining a pullorum disease free flock was in most instances due to a lack of observing sound eradication measures. More effective results would be obtained if all poultrymen would follow the laboratory suggestions more closely.

Two hundred and twenty-eight reacting birds were submitted to the laboratory for necropsy. The necropsy findings often aided in establishing the true status of a flock. No reactors were detected among the 584 tested fowl other than chickens.

This laboratory again participated in the annual pullorum conference of the Eastern States' laboratory workers. The purpose of this conference is to standardize and adopt uniform, sound methods which will prove practical and effective in pullorum disease eradication.

Among the blood samples submitted since August 1, 21,123 samples, representing 37 flocks, were tested with *Brucella abortus* antigen in 1-25 and 1-50 dilutions. All samples were considered negative.

An effort was made to determine the length of time *S. pullorum* will remain viable under various conditions. It was observed that the organism can remain viable on a dry piece of cloth in a Kolle flask for fourteen weeks and possibly longer.

The problem of "jelled serum" samples is being investigated. Results thus far show that the number of jelled samples may be greatly reduced if the freshly drawn blood is not subjected to low temperatures.

Laboratory Service—Pathology. (G. L. Dunlap). This service was used by 352 people, 71 making personal calls to deliver specimens or discuss poultry diseases. Ten hundred and seventy-nine specimens were examined, of which 1016 were poultry, the remainder consisting of other

domestic and semi-domestic animals. Approximately 15 per cent of all poultry examined were infested with parasites, led by coccidiosis, with tapeworm infestation second. Avian tuberculosis was diagnosed on two farms. Fowl cholera and fowl typhoid were not encountered.

An especially virulent strain of *S. pullorum* was isolated from mature stock and studied. This culture was physiologically and serologically identical to stock strains of *S. pullorum*. It produced death in two birds injected intravenously with 0.2 cc. of broth culture in 17 and 18 days, respectively, and the organism was again recovered. Two birds inoculated intratracheally with 0.5 cc. of broth culture were made visibly sick for a period of a week, but recovered. The primary lesion produced in these cases was a pericarditis.

A group of 25 day-old chicks were fed mash, which was contained in a bag contaminated with *S. pullorum*, for a period of three weeks. No mortality occurred from pullorum disease. At six weeks of age the agglutination test revealed two reactors. No more reactors were detected by the agglutination test applied at one and two weeks intervals over a period of seven months. *S. pullorum* was isolated from one of the two original reactors which were detected at the age of six weeks.

Farm and Station Bang's Disease. The laboratory, in assisting this project, has recorded 1339 agglutination tests.

Infectious Trachitis in Poultry. (C. S. Gibbs). Progress has been made in the study of infectious trachitis. The disease has been found to be caused by a filtrable virus. The virus has been demonstrated in the tracheal exudate and in the secretions from the kidneys of diseased birds. Some of the birds recovering from infectious trachitis have been found to persist as apparently healthy immune carriers. The viability of the virus is prolonged by freezing and drying.

Studies on secondary invaders in infectious trachitis have been made, and a laryngo-tracheal spirochete has been discovered. As far as is known at this station, this microorganism has not been observed before in poultry in the United States.

Details of these investigations are being prepared for publication.

THE WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon in Charge

For reports on experiments conducted at this substation in addition to these listed under the Waltham Field Station, see reports of the Departments of Botany, Entomology and Floriculture.

The Plant House. (P. W. Dempsey). Experiments have been continued in the construction, heating and operation of a sash-covered plant house. A twelve-sash hotbed was added to the plant-house model and one hot-water heater was used as a source of heat for both. This arrangement proved more satisfactory than using horse manure for hotbed heat. The interest in the plant house is indicated by the fact that 500 copies of plans and specifications have been sent out in response to requests for information.

Electric Hotbed. (P. W. Dempsey). After investigating the practical application of electricity for heating hotbeds in 1928, it was decided that the expense was too great, both for installation and upkeep. During the past year, however, the General Electric Company has introduced a new type of heater and thermostat, economical both in operation and cost. Plans are in the making for operating three hotbeds of four sash each with manure, hot water and electricity as sources of heat, in co-operation with the Edison Electric Illuminating Company of Boston. Notes on the comparative cost, temperature and other details will be kept.

Vegetable Variety trials. (P. W. Dempsey). Twelve varieties and strains of pole beans were tested. Kentucky Wonder proved to be the best both for the market and for home growing. The new variety of Italian Pole may replace the Kentucky Wonder because of its superior quality.

Seed of twelve strains of Calabrese broccoli were secured from as many different seedsmen. A decided uniformity was noted in all samples.

Thirty-seven strains and varieties of sweet corn were tested. Golden Sunshine was the outstanding early yellow variety and shows promise of replacing the once popular Golden Bantam. Golden Gem, a production of the North Dakota Experiment Station, is a very early yellow sort but too small to justify its extensive use for home or market planting.

Twelve varieties of peppers were compared. California Wonder, a new introduction, shows up well and is becoming popular with the growers. Red Sport of Oshkosh (seeds sent to Dr. Guba of this Station in 1929 by a private grower) shows great promise, and a separate plot will be devoted to this variety in 1931 for the purpose of further selection if the variety seems worthy.

Twenty varieties and strains of staked tomatoes, and fifty-four varieties and strains grown flat culture, were studied. There was no outstanding strain or variety.

Six strains of the popular Straightneck variety of summer squash were planted. No strain yet tried runs more than 50 per cent true to type.

Twenty strains and varieties of beets were seeded in two plantings. A great improvement has been noted in the strains of Detroit Dark Red offered by seedsmen the past three years. Crosby's Egyptian, however, remains the most popular and undoubtedly the best variety for Massachusetts growers.

Forty-nine strains and varieties of lettuce, of two plantings each, were made. The best lettuce ever produced at the Field Station was at just the right stage of maturity for Field Day. Many growers were impressed with the new strains of the so-called "White Big Boston" now sold by seedsmen under several names. It appears to be worthy of trial by any grower for sowing at any time during the season.

Conditions Affecting the Production and Vegetative Propagation of Washington Asparagus. Depth of Planting. (P. W. Dempsey). In 1928 two hundred selected one-year roots were planted two, four, six and eight inches deep. Next spring the beds will be cut for the first time.

Depth of Planting	No. of Plants	No. of Stalks	Average Stalks per plant
2	192	1700	8.8
4	197	1551	7.8
6	175	1209	6.9
8	154	1057	6.8

Fertilizer Studies. (R. M. Koon). The plots are located at Waltham, Concord and Eastham. Five acres, in total, are devoted to the plots. A comparison of fertilizer ingredients, time of application of fertilizers, amounts of fertilizer to apply, relation of high phosphoric acid to maturity, and relation of fertilizer to earliness are the principal problems being investigated. Although there were variations between the plots at the end of the 1930 season, there was no correlation between the variations and the treatment of the plots. This experiment will continue until 1934.

Greenhouse Lettuce. (V. A. Tiedjens). Very favorable reports from growers who tried out the Bel-May lettuce in the spring of 1929 resulted in a demand for seed. The Boston Market Gardeners Association sent one-half pound of the foundation stock to a California seed grower who returned 60 pounds of seed last August for distribution among the lettuce growers of this State. One-half of the lettuce produced in the greenhouses of Massachusetts during the season of 1930 is of the new Bel-May cross. It is a superior hotbed variety and shows promise as a satisfactory sort for the early transplanted crop in the field.

Improvement of Vegetable Varieties through Root and Seed Selection. (P. W. Dempsey). The foundation seed stock of the Field Station Hutchinson Carrot was grown as usual.

Further selection of the foundation stock of the Wyman beet was made, preparatory to having a quantity of seed grown under the supervision of the Oregon Agricultural College in 1931.

F_1 selections of the Blue Hubbard squash selfed in 1929 were planted and several excellent specimens were produced this season. Pollination was continud as before.

Seed from the best strains of Dwarf Horticultural beans from last year's trials as well as special strains from several new sources were planted. A few of the strains which showed some promise were saved for special study.

Perennial Ornamentals. (Ray M. Koon). Perennial gardens have been established for the purpose of observing pest attacks, the effect of cultural treatments, hardiness, and for the benefit of the visiting public who are interested in selecting plant material for their own homes. The plots include 675 varieties of flowering plants commonly known as perennials, 100 varieties of Iris, 60 varieties of roses, and 235 new varieties of peonies from the Cornell Surplus of the American Peony Society. A border of 380 deciduous shrubs and trees of eighty-five different species from which home lovers can make selections for simple and practical landscaping has been planted.

Field Day. The annual Field Day was held as usual at the Waltham Field Station the first Wednesday in August (August sixth) with about 900 market gardeners and florists attending.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station. C. V. Kightlinger, U. S. D. A., in Charge

Brown Root-Rot. (C. V. Kightlinger). Experimental work on brown root-rot of tobacco, conducted for the last several years at Whately, was terminated with the procuring of data on the 1929 crop. The results of these experiments will be combined with data from similar experiments conducted in Connecticut, Wisconsin, and elsewhere, for publication as a U. S. D. A. bulletin.

Black Root-Rot. (C. V. Kightlinger). Field experiments were begun this year (1930) at Amherst and at Windsor, Connecticut, to test certain strains of Havana seed tobacco produced by and obtained from Dr. James Johnson of Madison, Wisconsin, to determine their relative type, quality, resistance to black root-rot, and producing capacity under Connecticut Valley conditions. Although not all the data have been obtained yet, some of the strains seem promising. The experiments will be continued until definite information on the matter has been obtained.

Mosaic. (C. V. Kightlinger). Experiments have been carried on for more than a year to determine the extent of overwintering of tobacco mosaic viruses in different kinds of soils, under different conditions of temperature and moisture. All that can be said about results is that a high percentage of infection of mosaic is still being obtained from the materials treated as above described. Another set of similar experiments, begun a year later, is also being carried on for the purpose of verification of results already obtained.

PUBLICATION

Bulletins

260 Annual Report for the Fiscal Year Ending November 30, 1929. 60 pp. March, 1930.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

261 Ecological Studies of the Mexican Bean Beetle. Harvey L. Sweetman and H. T. Fernald. 32 pp. February, 1930.

The Mexican bean beetle was found in Massachusetts and Connecticut for the first time in 1929. A laboratory study of temperature and moisture conditions necessary for the development of the insect is here reported, and the results studied in relation to climatological data for New England. The following conclusions are drawn:

Climatic conditions in the Upper Austral Zone of Massachusetts, Connecticut and Rhode Island are favorable for the development of the Mexican bean beetle, and the insect may therefore be expected to become a serious pest. Conditions in the Transition Zone are less favorable, but the insect will probably become a pest in the lower portion of the Zone, with the injury becoming greatly reduced as the upper limits are approached. The Canadian Zone of New England does not have a physical environment suitable for the development of the beetle. A map of New England showing the three zones is included in the bulletin.

262 Intensive Grassland Management. R. C. Foley, E. J. Montague and C. H. Parsons. 17 pp. February, 1930.

The system of grassland management here reported is based on four distinct principles: (1) Division of area into plots; (2) use of concentrated fertilizers; (3) rotational grazing; and (4) combination of grazing and hay land. The system has been in operation here for two years and in spite of two extreme seasons, the first wet, the second dry, has given excellent results. The second year, in the face of a serious drought, it showed greater returns than the first year, and marked improvement in every respect. This two-year trial has proved that the grazing season may be lengthened and the carrying capacity of a pasture increased by the application of the four principles enumerated above, thus lessening the amount of barn feeding necessary.

263 Food Service in Massachusetts Rural Elementary Schools. Esther Davies. 19 pp. April, 1930.

This survey covered 222 of the 236 towns of less than 5000 population and included 57,600 pupils housed in 800 buildings. Of these, 567 had no food service whatever; 185 had hot drink or soup during the winter only; in 23 a meal was served during the entire school year; and in 23, milk was available for the children during the entire school year. There were 16,000 pupils who must always remain at school over the noon hour, and of these 6000 attended buildings where there was no food service. An examination of 1560 box lunches showed that 93 per cent of the children carrying them had no hot food at noon, and only 15 per cent brought milk. A description is given of eight different types of food service in use in buildings varying from the one-room schoolhouse with practically no facilities to buildings with full meal service. While the type of service which can be offered is limited by the physical equipment of the building, the examples show that no building is too poorly equipped to make some sort of hot food possible, at least during the winter months. Much remains to be done in establishing and improving school lunches; and with the growing tendency toward consolidation of rural schools, the question is becoming of greater importance each year.

264 Duration of Annual Molt in Relation to Egg Production. F. A. Hays and Ruby Sanborn. 14 pp. June, 1930.

A number of factors which may influence duration of molt are considered, as follows: environmental factors, such as hatching date; hereditary characteristics, such as age at first egg, intensity, winter pause, broodiness, and persistency; and physiological activities, such as previous egg production, 365-day production, and gain in body weight during the laying year. Relation of duration of molt to vigor and to second-year production is determined. The study was made with Rhode Island Red birds, and includes all females hatched from 1917 to 1928 and kept for two full laying years. In general, but little correlation was found between duration of molt and the factors studied. Highly intense layers and persistent layers, however, had the shortest molt period, indicating that the physiological process of molting and feather growth took place at a more rapid rate in heavy layers.

265 A Chemical Study of Cranberries. F. W. Morse. 16 pp. October, 1930.

A study of the chemical changes occurring in cranberries while ripening on the vines was made during two seasons. Total sugar was found to increase rapidly as the berries ripen, while total acid remained nearly unchanged. Cranberries do not acquire their maximum proportion of sugar until fully ripe on the vines.

Studies of cranberries in cold storage covered two seasons and showed that they steadily lose sugar by respiration. Total acid decreases also, but at a smaller rate. While cranberries remain sound they contain enough acid to maintain their tart flavor.

In the fall of 1929 there were received from growers in Massachusetts, New Jersey and Wisconsin 116 different lots of cranberries representing 61 distinct varieties. These were analyzed for total acid, total sugar and dry matter. The range in percentages of total acid was from 1.87 to 2.71 and in percentages of total sugar from 2.45 to 5.66. Thirty-five samples contained more than 4.5 per cent of sugar; 49, between 3.5 and 4.5 per cent; while 32 contained less than 3.5 per cent of sugar. The samples lowest in sugar were, as a rule, only partly ripe when harvested.

Ten varieties resisted decay in cold storage to the extent of 60 per cent of sound berries on April 1, 1930; four varieties had all their samples fully half rotted by January 15; and the remaining varieties were in that condition by the end of February.

266 Part-Time Farming in Massachusetts. David Rozman. 44 pp. October, 1930.

A study was made of three representative areas in Massachusetts, and with two main objectives. In Holden, in the central part of the State, the object was to determine the extent of part-time farming in the community as compared with regular agriculture. Of the 585 families engaged in some kind of farming, only 66 were full-time farmers. Land in crops and total value of products were almost evenly divided between regular and part-time farming. Although the production in most part-time farming enterprises is intended primarily for family consumption, the surplus sold amounted to over one-third of the total value of produce offered for sale by local producers. Part-time farming, therefore, excreised a considerable influence on local prices and marketing conditions of agricultural products.

In the other two areas, four towns adjacent to Lowell and four towns between Taunton and Fall River, the aim was to get a picture of the social and economic status of industrial and other laborers who are engaged in part-time farming. This mode of living was adopted for the most part as a means of increasing earnings and living more cheaply, or in the hope of improved health and better housing for their families. Two main types of part-time farming were found. The greater number had a regular job at which they worked, and did what farming they could in their spare time, with the help of their families. As a rule they raised vegetables or kept chickens or both, and the amount of work required was fairly regular throughout the year. A considerable number, however, engaged in truck farming or small fruit growing, devoting their entire time to it during the season and working at outside jobs only during the months when this type of farming does not require attention.

The development of part-time farming depends upon improvement in transportation facilities, shorter working hours in industry, and the location of industrial plants in small towns and rural communities. Indications are that part-time farming has been increasing in the State during the last decade and that the next ten or twenty years will show a further increase.

267 Hardy Woody Plants. Frank A. Waugh and Charles H. Thompson. 36 pp. October, 1930.

Hardy trees, shrubs, and vines are a very important feature of our civilization. Country roadsides and village streets are planted with trees; parks and playgrounds must have their trees and shrubs; but, most of all, the home grounds are not considered quite respectable unless trees, shrubs and vines are used to soften and civilize the architecture and the topography. Hardy woody plants have been under study for sixty-five years on the grounds of the Massachusetts Agricultural College, and this bulletin is intended to make some of the results of these studies available. A list of over three hundred plants is given, with a brief description of the chief characteristics of each and its performance under conditions found on this campus.

268 Frozen Sweet Cream as an Ingredient of Ice Cream. M. J. Mack. 11 pp. December, 1930.

The storage of cream in a frozen state is a satisfactory way of handling surplus cream for later use in ice cream, the quality of the frozen cream depending upon its initial quality, the length of time held in storage, and the storage temperature. Holding periods of less than six months and storage temperatures below 0° F. are recommended. Frozen cream mixes required a longer time in the freezer to reach a definite percentage of overrun than sweet cream mixes and showed a lower maximum overrun. Frozen cream mixes were higher in viscosity and contained slightly larger and more irregular-sized fat globules and clumps.

Ice cream mixes containing cream frozen with 0.5 per cent gelatin whipped but little better than plain frozen cream mixes. Homegenizing the cream before freezing did not improve its properties for ice cream making. Freezing cream with 10 per cent sugar was the most satisfactory method studied for storing frozen cream for later use in ice cream. The frozen sweetened cream melted more rapidly than plain frozen cream, was lower in viscosity and much more uniform in body. Ice cream mixes made from frozen sweetened cream were superior in flavor to plain frozen cream mixes, whipped considerably faster in the freezer, were lower in viscosity, and contained smaller fat globules and clumps.

269 Packaged Ice Cream. K. E. Wright. 12 pp. December, 1930.

The public has been slow to accept factory-packaged ice cream on account of its lighter weight and poorer texture.

The problem of weight can be most logically solved by drawing the mix at an overrun of about 50 per cent, although the light weight can be partially compensated by increasing the percentage of butterfat or by reducing the price to a weight basis or by a combination of these. Because of the low overrun required in packaged goods, it was found necessary to retard the overrun of easily whipped mixes in order to enable the drawing of the mix at the proper consistency. The substitution of butter for a part of the cream was found to be the most effective practical means of effecting a low constant overrun.

The texture of the ice cream as influenced by freezing was largely determined by the temperature of the semi-frozen product at the beginning of the hardening process. The rate of freezing in the ordinary freezer and in the hardening room was found to be a minor factor in influencing the texture in comparison to the initial hardening temperature. The size of the crystals determining the texture seems to be influenced by a specific range of temperature depending on the mix rather than by a progressive lowering of the drawing temperature of the mix. The results showed that the texture improvement due to gelatin and aging was caused by aging the gelatin, and that the effect on texture was more noticeable when a warm initial aging temperature was employed.

Control Bulletins

53 Tenth Annual Report on Eradication of Pullorum Disease in Massachusetts, 1929-1930. H. Van Roekel, K. L. Bullis and G. L. Dunlap. 23 pp. May, 1930.

54 Inspection of Commercial Fertilizers. H. D. Haskins. 64 pp. December 1930.

55 Inspection of Commercial Feedstuffs. Philip H. Smith. 44 pp. December, 1930.

56 Seed Inspection. F. A. McLaughlin. 42 pp. December, 1930.

57 Inspection of Agricultural Lime Products. H. D. Haskins and H. R. DeRose. 6 pp. December, 1930.

Meteorological Reports

493-504, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries.

Reports of Investigation in Journals

(Numbered Contributions[1])

101 Mineral Supplements for Dairy Cows. J. B. Lindsey and J. G. Archibald. Jour. Dairy Sci. 13:102-116. March, 1930.

102 Nitrogen Fixation in Field Soil under Different Conditions of Cropping and Soil Treatment. Leon A. Bradley and James E. Fuller. Soil Sci. 30:49-57. July, 1930.

104 The Effect of Initial Cooling Temperature on Gelatin in the Aging of the Ice Cream Mix. K. E. Wright. Jour. Dairy Sci. 13:406-415. September, 1930.

[1] Nos. 103 and 108 were cancelled. Nos. 109 and 110 have not yet been printed.

105 The Effect of Air Temperature on the Pathogenicity of *Rhizoctonia Solani* Parasitizing Grasses on Putting-Green Turf. Lawrence S. Dickinson. Phytopath. 20:597-608. August, 1930.

106 Pasteurized Dried Fruits. C. R. Fellers. Amer. Jour. Pub. Health and Nation's Health 20:175-181. February, 1930.

107 Nitrogen Availability in "Based" and Unbased Ammonium Sulfate and Ammonium Phosphate. A. B. Beaumont and T. R. Swanback. Jour. Amer. Soc. Agron. 22:811-819. September, 1930.

111 The Chemical Composition of Grass from Plots Fertilized and Grazed Intensively in 1929. J. G. Archibald. Jour. Agr. Research 41:491-501. September 15, 1930.

Other Contributions to Journals

(Unnumbered)

The Relation of Weather to the Quality and Price of Massachusetts Onions. R. L. Mighell and H. B. Rowe. Jour. Agr. Econ. April, 1930.

A Study of the Causes of Cull Apples in 1929. W. L. Doran and A. I. Bourne. Mass. Fruit Growers' Assoc. Rpt. 1930.

Effective Control Measures—Oil Sprays: Nicotine Activators. A. I. Borune. Mass. Fruit Growers' Assoc. Rpt. 1930.

Fruit Insect Pests of 1929. A. I. Bourne. Mass. Fruit Growers' Assoc. Rpt. 1930.

European Red Mite in New England Orchards. A. I. Bourne. Fruits and Gardens. March, 1930.

Spraying Recommendations in Relation to Bees. A. I. Bourne. Mass. Dept. Agr. Spec. Cir.

The Plum Curculio as an Apple Pest. W. D. Whitcomb. N. H. Hort. Soc. Ann. Rpt. 30. 1930.

Poisoning Plum Curculio Beetles—Mechanical Barriers of Dust and Spray Residue—Reducing the Cost of Nicotine Sulfate Sprays. W. D. Whitcomb. Mass. Fruit Growers' Assoc. Rpt. 1930.

The Grapefruit and its Juice. C. R. Fellers. The Glass Packer 2:509-510. December, 1929.

Roadside Farm Factories as New Factors in Food Preservation. F. P. Griffiths. The Glass Packer 2:493-519. December, 1929.

Canned Foods Are the Freshest Foods. C. R. Fellers. The Canner 70:17-18. June, 1930.

Utilization of Cold Packed Fruits in Frozen Dairy Products. C. R. Fellers and M. J. Mack. Fruit Products Jour. 9:106-109. December, 1929.

Sodium Benzoate and Benzoic Acid as Preservatives for Cider and Other Fruit Juices. C. R. Fellers. Fruit Products Jour. 9:113-115. December, 1929.

Some Newer Developments in the Control of Apple Diseases. E. F. Guba. Mass. Fruit Growers' Assoc. Rpt. 1930.

Automatic Control of Relative Humidity and Temperature Supplementary to Sash Ventilation in Greenhouses. E. F. Guba. Market Growers Jour. June 1, 1930,

Fundamental Principles in Forcing Gladiolus. L. H. Jones. New England Gladiolus Soc. Yearbook, 1930.

CHANGES IN STAFF, DECEMBER 1, 1929, TO NOVEMBER 30, 1930

Appointments

Bennett, Emmett, B.Ed., Research Assistant in Chemistry, January 1, 1930.

Clague, John A., B.S., Research Assistant in Horticultural Manufactures, September 1, 1930.

Cleveland, Maurice M., B.S., Fellow in Horticultural Manufactures, September 20, 1930.

Donley, J. Elizabeth, B. A., Laboratory Assistant in Agricultural Economics, September 22, 1930.

Donnelly, Edward B., Technical Assistant in Floriculture, February 1, 1930.

Flint, Oliver S., B.S., Assistant Research Professor, Poultry Disease Elimination Law.

Jones, William L., B.S., Fellow in Agronomy, October 1, 1930.

Koon, Ray M., M.S., Research Professor in Vegetable Gardening, in charge of Waltham Field Station.

Foley, Richard C., B.S., Research Assistant in Animal Husbandry, April 1, 1930.

Larsinos, George J., M.S., Junior Chemist, Fertilizer Law, October 1, 1930.

McLaughlin, F. A., B.S., Assistant Research Professor, Seed Law, September 1, 1930.

Merriam, Oreana A., B.S., Laboratory Assistant in Home Economics Research, July 1, 1930.

Parkinson, Leonard R., Technical Assistant in Animal Nutrition, December 21, 1930.

Spelman, Albert F., B.S., Junior Chemist, Feed Law, January 13, 1930.

Stuart, William M., Jr., B.S., Research Assistant in Agronomy, October 1, 1930.

Voorneveld, Madaline, B.S., Laboratory Assistant in Home Economics Research, September 8, 1930.

Washburn, Doris E., B.A., Research Assistant in Farm Management, September 1, 1930.

White, Harold E., M.S., Assistant Research Professor in Floriculture, January 1, 1930.

Resignations

Alcock, James R., Technical Assistant in Animal Nutrition, December 21, 1929.

Church, Cornelia B., B.S., Laboratory Assistant in Home Economics Research, July 7, 1930.

Fernald, Henry T., Ph.D., Professor of Entomology and Head of Department, June 30, 1930.

Jones, John P., Ph.D., Research Professor in Agronomy, June 30, 1930.

Kelley, Joseph L., Technical Assistant in Cranberries, November 1, 1930.

Kelly, Oliver W., M.S., Seed Analyst, June 30, 1930.

Kuzmeski, John W., B.S., Junior Chemist, Feed Law, December 31, 1929.

Rice, Cecil C., B.S., Research Assistant in Horticultural Manufactures, September 1, 1930.

Shilling, Katherine E., A.B., Laboratory Assistant in Agricultural Economics, September 15, 1930.

Tiedjens, Victor A., M. S., Assistant Research Professor in Vegetable Gardening, June 30, 1930.

Zielinski, John B., Jr., B.S., Junior Chemist, Fertilizer Law, September 30, 1930.

Publication of this Document Approved by the Commission on Administration and Finance.

2500-3-'31. No. 1535

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 272 March, 1931

Experiments With Hedges

By Frank A. Waugh

Hedges are coming back into fashion. They always were both useful and beautiful when properly placed and well kept. They serve as boundaries on property lines, as enclosures to gardens, as windbreaks, and for privacy in the home grounds. Many species of trees and shrubs will make good hedges under suitable management. This fact gives range for critical choice of materials. The Department of Landscape Architecture, Massachusetts State College, has maintained a demonstration and experimental garden for testing hedges for ten years, and the results of this work are herein reported.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

EXPERIMENTS WITH HEDGES

By Frank A. Waugh, Professor of Landscape Architecture

In the spring of 1921 a garden of sample hedges was planted on the college grounds. These hedges were intended originally merely for demonstration purposes, to give the students in landscape architecture and in horticulture an opportunity to observe the adaptability of different species to hedge culture, and to get a more objective idea of methods of management. The demonstration proved so interesting, however, that it was extended by making another plantation in the spring of 1926.

As time went on these plantations came to take on more and more of an experimental character. So much interesting information has been collected that it seems proper now to make a report upon them.

As a matter of fact hedges are a very important part of the home grounds, or small village home lot. The modern tendency towards smaller and smaller grounds has required more formality of treatment and a greater effort to secure the necessary privacy for the family. In pursuit of either object a good hedge is a valuable asset.

These hedges were planted in sample rows, each 50 feet long with the rows 10 feet apart. In all cases the rows were placed in an east-west direction, thus having the sun on one side. The soil was dry, well drained (rather too well drained), and gravelly. The ground has been lightly cultivated to keep down weeds, but no other special attention has been given. No fertilizers have been applied nor any irrigation given. Almost any home lot anywhere in New England would have conditions at least as favorable as those under which these hedges have been grown and maintained.

The original plantation included 21 species and varieties. A few of these failed or were discarded for sundry reasons, their room being taken by other subjects.

The second general experiment was begun in the early spring of 1926. At this time 15 hedges were set in soil similar to that where the first plantings were made: that is, dry, gravelly, warm and well drained. Rows were set east and west, but plants were placed more closely than in the first planting, from 12 to 24 inches apart, depending on their habit of growth. A few of these species and varieties were duplicates of those in the first planting, but mainly they represented new types.

The two lots are reported together in the following pages, along with a few other species tried out separately on other parts of the college grounds. It must be observed that the notes here recorded refer only to species and varieties actually tested here. It is clearly understood that many other hardy trees and shrubs are well adapted to the same purpose.

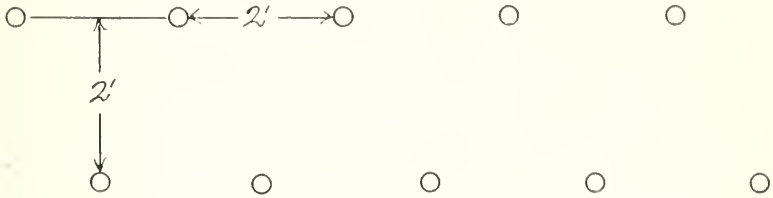
Planting

In the original plantings in our experimental garden all hedges were spaced with plants three feet apart in the row. This figure was chosen as a compromise and with the intent of treating all species alike. It soon appeared, however, that for best results different species should not all be spaced alike;

also that three feet is too wide except for species of strong growth and for large hedges.

From our subsequent experience it would seem that the three-foot spacing is satisfactory for hemlock, white pine, arborvitae and evergreens generally; also for willows, hydrangeas, spireas, etc., when grown in heavy unsheared borders. A spacing of 18 inches to 2 feet will be satisfactory for hemlock or arborvitae in a small, closely-pruned hedge; also for large, sheared hedges of privet, winged euonymus, Japanese quince and similar species. Average garden hedges of privet, acanthopanax, buckthorn, barberry, snowberry, etc., should be spaced 14 to 18 inches. Small hedges or borders of dwarf arborvitae, wintercreeper, box barberry, dwarf box and similar slow-growing sorts may be spaced at 8 to 12 inches.

Unless room is at a special premium it is good practice to plant a hedge in a double row, "staggering" the plants, as shown in the accompanying diagram. The spacings there suggested, viz., two feet in the row with rows two feet apart, may of course be increased or decreased at need, though the figures given are quite favorable for average conditions.



Staggered Planting of Double Hedge Row

Aside from conscientious pruning a hedge demands very little care. It must be supposed, of course, that it is originally planted in reasonably good soil—a supposition not always satisfied in experience. Also attention must be given to the matter of shade. No hedge will thrive under trees, though this, too, is sometimes asked of them. Barberry and privet will tolerate considerable shade, especially the shade of buildings, since a building does not rob the soil of water and plant food.

Water is always in demand by growing plants, and on dry soils hedges suffer and sometimes die outright from drought. It may be feasible to water a newly planted hedge through its first year or two; but, outside of places where irrigation is the established practice, every hedge will be obliged finally to subsist on its own water supply.

Heavy applications of fertilizer will seldom be justified. Nevertheless, some feeding from year to year may be quite desirable, since a prime point in hedge management lies in keeping the plants always in a state of healthy growth. For this purpose nitrogen is required above all other elements. Barnyard manure is especially useful and especially hard to come by. Of chemical fertilizers those carrying abundant nitrogen are to be preferred. Applications should be made in early spring, just as growth is starting (April) and should be withheld after June 1.

Finally it must be remembered, as elsewhere suggested, that no hedge is

immortal. The best plants under the most favorable circumstances will sometime grow decrepit, and the hedge will begin to look ragged and frayed. After one or two rejuvenations, perhaps before, it will become necessary to abandon the hedge, root it out, and make a new start. Such drastic procedure is troublesome and expensive, it leaves the garden most unhappily exposed for a period of two or three years, and it brings sentimental strains which are sometimes far from negligible. Nevertheless the garden owner may as well harden his heart, fortify his pocketbook, and withstand the counsel of delay. This is the way of all hedges.

Forms of Hedges

It will help to understand the following notes, and it may be of practical value in using this information, to understand that hedges may be grown in several different forms. The most common are as follows:

1. Sheared hedges, usually from 3 to 10 feet high. This is what is commonly understood by a hedge.

2. Unsheared hedges, in which the plants are set in rows as for No. 1 but are allowed to grow freely, following substantially their natural habits. Such a hedge is less formal but often efficient and adequate, separating two properties or two parts of one garden or park. The plants usually need an annual pruning, preferably in January or February. At this time the proper technic is to cut out old wood from the bottom of the plants, leaving the fresh one-year-old canes.

3. Edgings. These will usually be formally sheared as in No. 1 but will be much smaller in their dimensions, usually a foot high or less. Obviously the treatment must be more drastic than in the management of either of the other forms.

Pruning

While no set experiments in hedge pruning have been carried through upon these plantations, there has necessarily been considerable experience accumulated. Each of these hedges has been pruned annually; certain hedges in certain years have been pruned twice; and in a few instances several prunings have been practiced upon some particular hedge in a given year to serve some special object. The results of all these experiences may fairly be summarized for the practical benefit of those who are planting hedges or who have old hedges under management.

1. It is essential to begin early. (a) The hedge plants should be rather closely cut back at planting time. (b) If they grow rampantly the new shoots should be headed back late in May or early in June of the first year. Certainly the plants should all be cut back again in early spring (February preferably) of the second year. The purpose of this early pruning is to force a thick growth at the base of the plants.

2. During all the formative years this severe pruning should be followed. In February the shoots of the previous year's growth should be shortened one inch to one foot, (usually about five inches) of one-year-old wood; though obviously much will depend on the species being pruned and on the amount of annual growth.

3. Annual summer pruning is often desirable, in addition to spring

(dormant) pruning, especially with rapid-growing deciduous species, such as privet, acanthopanax, etc. This summer shearing should be given immediately after the plants have made their first strong growth. The time will usually fall in late May and seldom later than the first week in June.

4. After a hedge has reached the stature prescribed for it, pruning aims to keep it within its limits and also to maintain the plants in a healthy growing condition. To accomplish these purposes it will be necessary to watch carefully the behavior of the plants and to remember that summer shearing tends to check growth and weaken the plants, whereas dormant pruning is more inclined to favor wood production. Summer pruning can thus be practiced on a hedge which is thrifty, but one which shows signs of debility should be cut back in winter and left to grow freely in summer.

5. Signs of decrepitude, decay, disease or advancing age are apt to appear in any old hedge. These may be due to drought, lack of fertilizers or attacks of insects; and all such cases will presumably receive appropriate remedy. From the standpoint of pruning, however, the practice should be to cut back rather heavily in February, perhaps cutting back into wood three or four years old, thus possibly marring the outline of the hedge for the time, the object being to stimulate a new growth in the old plants.

6. In extreme cases it will be good practice to renew the hedge completely by cutting back to the ground or near it, thus making an entirely new beginning with the old plants. This plan has been carried out successfully with several species, including privets, Thunberg spirea, buckthorn, willow, Tatarian honeysuckle and some others.

Renewals

It may be well to remark further that no hedge should be regarded as quite immortal. The treatment which it receives is highly artificial and somewhat drastic, so that there need be no wonder if after 10 or 20 or 40 years the hedge becomes so ragged that it may better be abandoned. There are times when good sense would advise digging out an old hedge, root and stem, cleaning the ground, fallowing for a year or more, and making a new start with fresh young plants, perhaps of some other species.

Even more frequently the emergency arises in which a section of a hedge requires replanting. A few plants are destroyed by insects or by a runaway automobile, or by fire or by winterkilling. These dead plants may be removed, the ground redug and freshened as much as possible, perhaps the old exhausted soil removed and replaced with fresh loam, new plants set in and forced to their best growth by special care. Under favorable conditions such repairs may achieve quite satisfactory results without more than two or three years' waiting.

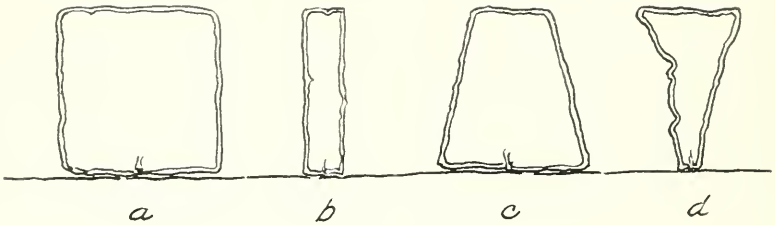
Shaping the Hedge

Along with pruning comes the problem of shaping the hedge. This is particularly important during the early years, but never ceases to have a considerable influence on results.

In general it may be pointed out that the amateur is apt to make his hedges too thin and narrow. He thinks of the hedge as a wall between him and the outside world and, drawing his analogy from the house in which he

lives, he thinks that a wall a foot thick must be rather heavy. It is not at all uncommon to find hedges pruned to a width of 18 inches or 2 feet. It is much better to prune them to a width of 3 or 4 feet, even 6, 8, or 10 feet for large hedges. The side growth supplies branches to carry foliage and keep the hedge plants alive and healthy.

As everyone must have observed, the great defect of hedges is to thin out at the bottom, lose their lower branches, and eventually be entirely open for some space above the ground. A large share of this trouble is due to the neglect of early pruning, that is, of careful work done during the first years while the hedge is being formed. Much of it is due also to pruning the side branches too close. Some of it is caused by improper shaping of the hedge.



Cross-section of Hedges

a. Good section. b. Too narrow c. Best section
d. Degenerate unpruned hedge

The accompanying sketches will indicate more clearly what the desirable procedure is. The wide hedge has more leafage and will remain longer in good health; at the same time it will be much more efficient in shutting off observation from the outside or in protecting the garden from wind and storms. Furthermore, if the hedge is pruned so that it has a cross section like a letter A instead of a letter V, the lower branches can receive much more sunshine and will therefore make more growth and live longer.

After a wrong start has been made with a hedge it is difficult to change its cross section. In cases where the trouble is serious, for example, where the lower branches have entirely died away, it may be feasible to cut the hedge back to the ground and begin again as mentioned above. In milder cases severe heading in at the top of the hedge may force the side branches into growth, thus enabling one to broaden the cross section and improve the general surface of the garden hedge.

Notes on Species and Varieties[1]

Abies balsamea. Balsam Fir. A well-known timber tree of the north woods, found native in cold swampy lands and at higher altitudes. This species is extremely ill adapted to the dry soil and sunny exposure where it is planted in this experiment. The purpose of using it here has been to observe what might be accomplished under the most adverse conditions. The plants have lived for 10 years without losing any, but the growth has been poor and the hedge is obviously not a success. The hedge has been sheared to a height of 3 feet 6 inches. Apparently the balsam fir will stand shearing as well as

[1] The nomenclature in this bulletin follows Standardized Plant Names, Salem, 1923.

Acanthopanax, as thorny as its name, fresh and green, makes a good hedge

spruce, and on cold northern slopes and heavy soil it might possibly be a satisfactory choice for hedge planting.

Acanthopanax pentaphyllum (no vernacular name). A strong, very hardy shrub, stiff and upright, moderately thorny; foliage 5-palmate, glossy and healthy. This makes an excellent hedge if kept conscientiously pruned. The example in this experiment stands 3½-4 feet high and is 3 feet wide. Unless well cared for it thins out at the base.

Japanese Barberry is a favorite hedge plant, rather dwarf and thorny.

Japanese Barberry in its winter aspect—always beautiful

Artemesia pontica. Roman Wormwood. Plant herbaceous or only half-shrubby, grows 6-8 feet with attractive silvery-gray foliage. It has proved necessary to cut the plants back to the ground annually. For a quick, temporary hedge this species is worthy of consideration; but after a few years the plants deteriorate and must be replaced. On the whole it is not recommended.

Berberis thunbergi. Japanese Barberry. A very hardy, strong shrub, very easily grown, adapted to a wide variety of soils and exposures, includ-

Box Barberry

Suitable for a small low hedge or border one or two feet high

ing partial shade. Is distinctly thorny—so much so as to be disagreeable in the intimacy of a small home garden. Stands shearing well. Several plantings on the college grounds are usually pruned to a height of about 3 feet with equal breadth. Making due reservations for the thorny character already mentioned, this must be regarded as one of the best hedge plants in the catalog.

Box Barberry (Sometimes cataloged as *Berberis thunbergi minor*). A very dwarf form of the Japanese barberry suitable for low borders and small hedges generally. Will submit to partial shade, though experience indicates that it is less pliable in its adaptations than the common Japanese species. Two hedges in different locations have both required replantings. The experimental hedge planted 1926 is now 11 inches high and 10 inches broad. Except for its somewhat capricious habits this variety may be recommended. When it does well it makes a very good small hedge, and it can be kept to smaller dimensions than most hardy plants.

Dwarf Box
The plants are fragrant, evergreen and old fashioned—all strong qualifications

Buxus sempervirens suffruticosa. Edging Box.[2] This dwarf box is somewhat hardier than the species. In edgings planted in the college gardens in 1925 not a single plant has been lost out of several hundred. It has had some protection each winter, however, i. e., a few pine branches have been thrown over it to hold the snow. Apparently this variety is dependable for this locality, and it is indeed a very attractive plant for low garden edgings.

The type *Buxus sempervirens*, has been grown on the college grounds, but is not reliably hardy.

[2] The nomenclature here follows Rehder, Manual of Cultivated Trees and Shrubs, 532. New York, 1927.

Caragana arborescens. Siberian Pea-tree. A stiff upright large shrub or small tree, somewhat thorny and very hardy against cold; foliage fine and pinnate, but in present surroundings yellowing and falling away soon after midsummer.

This is a favorite hedge plant in parts of Canada and the Northwest, and is worthy of further trial in Massachusetts, especially for higher altitudes and cold exposures; but in this experiment it has proved a highly qualified success—more straightly speaking, a moderate failure.

Japanese Quince
Has beautiful flowers and makes a good low hedge

Cydonia japonica. Flowering Quince. This species is a prime favorite for lawn planting, its pink, red or orange flowers, borne in abundance in May, being its chief attraction. The fruits, which usually hold on quite into the winter, are fragrant and pleasing also. The flowering quince has been somewhat frequently used as a hedge plant, but the first planting here, now 10 years old, has never made sufficient growth to fill out its allotted space. A second planting, 1926, is doing better under somewhat better conditions. Experience here would indicate that this species may be used for garden hedges where a division of land spaces chiefly decorative is desired; but that for a solid sheared hedge some other species would better be chosen.

Elaeagnus longipes. Cherry Elaeagnus. A good clean shrub, very hardy, with attractive gray-green foliage. This ought to make a good hedge. It has been highly recommended, presumably on the basis of successful experience. However, in the present experiment it has consistently refused to make good. Several plants have died and have been replaced. Growth is irregular and the row has never at any time assumed the aspect of a garden hedge. It is certainly worthy of further trial under other conditions, but in this case it must be reported as a failure.

Winged Euonymus
A very attractive shrub for hedges (Acanthopanax shown at right)

Euonymus alatus, WINGED EUONYMUS. A fine hardy shrub from the Orient which is especially adapted to New England conditions. Growth upright, branching, twigs with interesting corky ridges, foliage bright green, always clean and healthy, flowers and fruits inconspicuous. Hedge set in 1924, now 6 years old, has been closely sheared to height of 2 feet 4 inches and spread of 2 feet 6 inches and has thrived under this drastic pruning. It is plainly one of the best deciduous hedges in the experiment. The winged enonymus may be cordially recommended for hedge planting.

Presumably other species of the same genus would be worthy of trial, e. g., *E. americanus*, *E. europaeus*, and *E. nanus*.

Winged Euonymus in snow, showing that many deciduous plants have pleasing character in winter

Wintercreeper
Low evergreen hedge or border only a foot or two tall

Euonymus radicans, WINTERCREEPER. A dwarf evergreen shrub, not fully erect but sufficiently so to form a low garden border. It prunes well and may be freely chosen for the use here indicated. The experimental hedge planted in 1926 is now about 10 inches high and 14 inches wide.

Wintercreeper in winter, its evergreen foliage contrasting delightfully with the snow

Gleditsia triacanthos. COMMON HONEYLOCUST. A hardy tree native to the Middle States. Too large and strong for a small hedge, but adapted to heavy duty. Foliage fine, pinnate; shoots stiff and strong, set with long and extremely efficient thorns. For a "bull-tight" hedge, designed to turn back all intruders, this would be quite the thing. However, it is altogether too harsh for any domestic use. Moreover it cannot be pruned to make a shapely hedge of moderate size.

Hydrangea arborescens. SMOOTH HYDRANGEA. Vigorous hardy shrub making an annual growth of 4-6 feet; stems straight and rather coarse, foliage large, coarse, clean, and free from disease; flowers white, abundant, in large showy trusses, lasting throughout the late summer. This shrub does not make a hedge, strictly speaking, but can be used for an informal border marking. The practice here is to cut it down to the ground early each spring, a treatment under which it thrives and yields its best blossoms. These blossoms are its principal merit.

It should be noted that this is not the PEEGEE HYDRANGEA (*H. paniculata grandiflora*), the variety most commonly grown. The Peegee hydrangea may also be used in the same manner, though the Smooth hydrangea is better.

Smooth Hydrangea bears quantities of flowers but cannot be sheared into hedge form.

Ligustrum amurense. AMUR PRIVET. A strong hardy shrub admirably adapted for hedges. Plants make an annual growth of 20-30 inches, the hedge is 4 feet high and 4 feet broad, in good condition except that it is thinning out somewhat at the bottom.

The privets are nearly all good hedge materials. They stand shearing well, are perfectly clean and hardy (with rare exceptions), and have the advantage that they will grow reasonably well in shade. The Amur privet is the best for general hedge use in this vicinity where the California privet is

not hardy and the European privet (*L. vulgare*) is subject to disease. For best results a privet hedge should be sheared twice or three times each year and every year from its first planting.

Ligustrum lodense. Dwarf Privet. A very dwarf form with thickly growing top and small foliage. The plants appear to be lacking in vigor and it has proved impossible thus far to keep vacancies filled and so impossible to make a shapely hedge. Those plants which do live and thrive, however, present a most attractive appearance, shearing well and making an admirable small dense hedge. This is probably worthy of further cautious trial.

Amur Privet
The best privet for hedge use, and the privets are all good

Lilac. Leon Simon. This hedge, set in 1926, was intended to show what might be expected of modern hybrid lilacs when used as hedges. The common lilac has long been used as a garden border plant, i. e. in unpruned hedges. Six years' experience with this hybrid variety, however, shows that the growth is slower, more irregular and more uncertain than the common lilac and suggests that the hybrid lilacs will hardly meet the requirements for hedge use.

Lonicera tatarica. Tatarian Honeysuckle. A strong coarse shrub, with stiff upright stems, very hardy against winter cold; the foliage has a tendency to grow rusty and thin out early in the fall. As a hedge it is inclined to overgrow and to become stiff and stubby under the necessary pruning. This hedge had a height of 6 feet and a width of 4 feet 6 inches. Not recommended for general use.

Maclura pomifera. Osage-orange. A hardy tree, natve to the Middle States, and much used for farm hedges because of its sturdy growth and repellent thorns. Stands shearing well. The plants in this garden, however, were set as late as the spring of 1930, and though the first year's growth was promising, no practical observations can be reported.

Malus ioensis, var., Bechtel Crab. A showy and popular ornamental apple; growth coarse and open, foliage coarse and badly attacked by yellow rust (aecidium). Planted 1924. Has been a total failure as a hedge plant. As this failure seems to follow from the habit of the plant rather than from lack of adaptation to local conditions, it would appear that the Bechtel crab may be definitely written off the list of hedge plants. Growth is too coarse and the plant does not thicken up under the pruning shears.

Myrica cerifera, Bayberry. A clean and desirable native shrub especially well-known in the region along the seacoast where its waxy berries are eagerly sought for decorations and for candle-making. It grows slowly with a twiggy, bristly head bearing shiny very attractive foliage. The soil where this lot is planted is probably too warm and dry, but the plants have lived and thrived, except for their very slow growth. Shearing has not been tried, and seems unpromising; but for a dwarf, unsheared hedge, in regions where the species is hardy, particularly in coastal regions, it could be cordially recommended. Its appearance is notably pleasing to the discriminating eye. The habit of slow growth is less marked as the plants get older and become established. Records taken in this experiment show an annual growth of 18 to 30 inches in recent years, indicating that some shearing might be given. The hedge after 10 years' growth and without pruning is now 3 feet 6 inches high and looks better with each succeeding year.

Mountain-Holly
A novelty in the line of hedges, but promising

Nemopanthus mucronatus, Mountain-holly. A hardy native shrub, somewhat rare in nature and rarer still in horticultural use, but excellent for planting nevertheless. Growth moderate, upright, good foliage, interesting red berries in autumn. Planted 1926, it now gives promise of making a good hedge. It seems to submit graciously to the pruning shears. Attractive as a novelty and thought worthy of further trial.

Picea excelsa. Norway Spruce. A European species very well-known and widely grown in America. It makes an admirable hedge, preferably in fairly large dimensions, 6 feet tall or over. It stands shearing well and makes a firm thick surface. It prefers fairly strong, cool soil. It will grow almost anywhere, but on dry, warm soil it soon becomes ragged. This "moth-eaten" effect is increased if the plants are attacked by the spruce gall louse, as in this vicinity they often are.[3]

Norway Spruce
A tall sturdy hedge of rapid growth

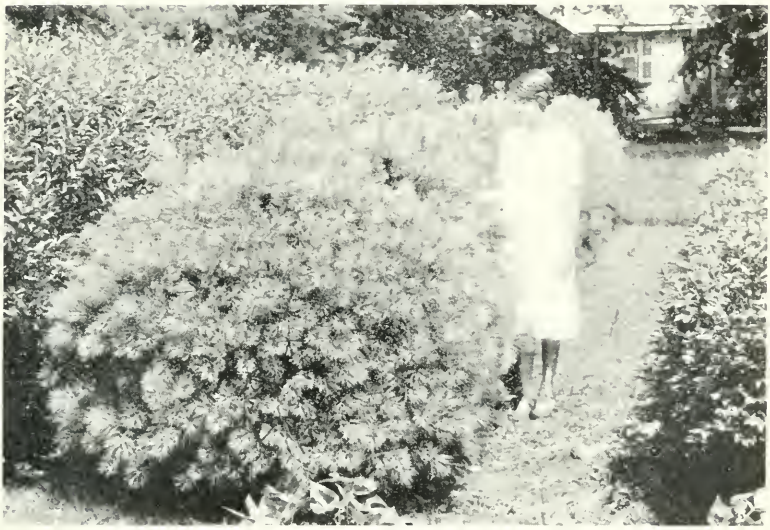
[3] Spruce Gall Louse. This insect causes small, green, cone-shaped, multiple-celled galls to appear at the base of young shoots in early summer. The twig beyond these galls is often killed and almost invariably deformed. In case of heavy infestation the vitality of the tree is lowered and its appearance marred.

During the winter the young lice are located in folds of the bark or clustered around the base of buds, chiefly on the terminal growth. Light yellow eggs are deposited in early spring, soon after new growth starts. They are usually enveloped in a white woolly mass of waxy filaments which makes them quite conspicuous. The young lice usually crawl to the base of tender, growing shoots and are soon enclosed in cells or chambers of the young forming galls. Galls are at first green in color but later become darker, and in late July or early August the cells open and the mature, winged lice escape. These produce the young lice which winter over on the twigs.

In the case of a few small trees, it is possible to control this pest by removing the young, newly-formed galls. This should be done in June or early July. Thorough spraying of infested trees in April, with a contact insecticide, has proved successful. This is aimed to destroy the young lice wintering over on the twigs. Especial care should be taken to thoroughly cover the trees, particularly the terminal twigs.

Experiments with various oil sprays have given excellent control. Oil sprays may be used at weaker strengths than is necessary for general orchard practice. They should be applied on warm, sunny days with temperatures of 40° F. or above, and preferably during the middle of the day. Oil spray should always be applied while the trees are in dormant condition before new growth starts in the spring; otherwise more or less injury may result.

This account of the spruce gall louse is contributed by Professor A. I. Bourne, Entomologist of the Experiment Station.



White Pine
Surprisingly adaptable to hedge use; shears well

Pinus strobus. WHITE PINE. Well-known evergreen tree native to New England forests and highly prized as a timber tree; also for ornamental planting. The fact that this tree can be sheared into a very satisfactory hedge comes as a great surprise to most persons. Two different lots have been used

White Pine hedge in winter when it reveals extraordinary beauties

in this experiment. The older planting after 10 years is a thick, smooth, handsome hedge 4 feet high and 4 feet broad. In summers of drought the foliage has yellowed somewhat and thinned out perceptibly, yet at all times this hedge has been the admiration of visitors. Regular and careful pruning is required, preferably twice each summer. On suitable soil with reasonable attention the white pine may be confidently planted for hedges and pruned to any moderate dimensions, from a height of 4 feet up as far as a ladder and pruning shears will reach.

The second lot, planted in 1926, is merely repeating the history of the first planting.

These fine hedges are surpassingly beautiful when loaded with fresh snow.

Rhamnus cathartica, Common Buckthorn. A strong hardy shrub formerly a favorite hedge plant in New England but lately almost forgotten. Strong upright growth, foliage dark green, fresh and clean, not subject to disease or insect attack. Two lots have been used in the present experiment. The first lot were poor plants, old and overgrown, and were planted too far apart (3 feet). After several years of failure they were cut to the ground (spring of 1929) and are now giving promise of better behavior. The second lot, planted 2 feet apart and heavily cut back (1926) have done well though they have not yet shaped into a permanently satisfactory hedge. Experience here would indicate that the common buckthorn is suitable for fairly large, heavy hedges, 6 to 10 feet high and of nearly equal width.

Rhus typhina laciniata, Shredded Sumac. A curious horticultural form of the native staghorn sumac having very much dissected foliage which gives a surprisingly interesting and decorative effect. The plant grows very vigorously, upright or sprawling, suckering. It was included in the experimental plantings of 1926 with the expectation that it would prove the most refractory plant that could be chosen for hedge making—an expectation fully justified in experience. It is absolutely and altogether unsuited to any sort of hedge use.

Rose, F. J. Grootendorst. In habit of growth this resembles the parent. *Rosa rugosa*. It is hardy, very thorny, strong and upright, with coarse, glossy foliage. The bright red flowers, however, are borne on loose trusses throughout the summer and are fairly good. Like *R. rugosa* this seems adapted to the seashore, but will thrive in any garden with even moderately good soil. It does not lend itself to shearing, but will make an excellent division line with a minimum of care. The old stems should be cut out annually down to the ground. Young shoots will make a growth of 2½-4 feet.

Rose, Lord Jeffery. This is a form of the native *Rosa palustris* (*carolina*) of cleaner, stronger growth than the type, less inclined to sucker, and with better blooms. On the dry soil of this garden it thrives and makes a delightful border, but does not suit well with the pruning shears. For a somewhat informal border it may be cordially recommended.

The type, *Rosa palustris*, has also been tried but proves to be unpleasantly weedy.

Rosa multiflora, Japanese Rose. A strong sprawling hardy shrub with attractive flowers and fruits. Planted 1921, removed 1924. Proved to be too wayward for any form of hedge.

Salix caprea, Goat Willow. This is one of the many varieties known as a "pussywillow" and is desirable for spring forcing. If cut to the ground early each spring (February) it makes a growth of 5-6 feet and forms a good garden border. Even in this capacity it has many superiors.

Salix vitellina. Golden Willow. When full grown this species makes a moderate tree, but it can be cut back to any extent desired. In the present experiment it has been cut back to the ground early each spring. From this point it throws up a thick growth of slender shoots to a height of 6-8 feet. These bear silvery green foliage and present a sunny, pleasing appearance throughout the summer. The best effect, however, is that shown by their glowing yellow shoots during the winter, brightening toward spring. As a sheared hedge this species is highly impracticable; but as an informal border, cut back annually as described, it has real merits.

Thunberg Spirea cannot be successfully sheared but makes a pleasing boundary planting

Spiraea thunbergi. Thunberg Spirea. A Japanese shrub very popular in general ornamental planting. Growth slender and willowy; foliage fine, delicate and attractive; flowers small, white, abundant. This species has done well in the hedge plantation but has never submitted gracefully to any shearing. If it is cut back to the ground every year, or every other year, it makes a soft and pretty garden border. Treated as here recommended it makes a border approximately 3 feet tall and 3-4 feet broad. Its fine texture, graceful habit of growth, delicate flowers, and general refinement suggest its use near dwellings and in other intimate surroundings.

Symphoricarpos racemosus, Common Snowberry. A popular native shrub, its snow-white fruits persisting into the winter and being much admired. The habit of growth is slender and arcuate and not adapted to barrier hedges where shearing is required. Nevertheless moderate pruning will not injure the plants. With light shearing or none (annual removal of old wood from the bottom) this makes a desirable garden border.

Thuja occidentalis, American Arborvitae. A very hardy and well-known native evergreen tree, generally found in swampy lands or lake shores. It has long been known as a hedge plant of great value. The first planting in these

The Snowberry makes a graceful, pliable border, but does not shear well.

experiments was made in 1921 and, in spite of the dry soil, has never faltered. No replacements have been required, and though some browning of foliage could be noted in dry summers, the general appearance has always been good. Experience here merely confirms the popular verdict that American arborvitae is one of the best hedge plants in the entire list, adapted to a considerable

Arborvitae hedge ten years old—one of the best of all hedges

Arborvitae six years planted and clipped to a very small garden edging

range of soil conditions and exposures, amenable to almost any kind of treatment, and suited to many forms of garden use.

A second planting of this species was made in the spring of 1924 with small plants 4 inches high set 6 inches apart, with a view to testing the results of very close pruning. It was thought that perhaps a small garden border or edging might be grown. The results after six years are fairly satisfactory. It has been possible to keep these plants in reasonably good health and growth and yet prune them to a height of 7 inches and a width of 6 inches.

Arborvitae covered with snow and even more at home than in the summer

(It may be remembered that the arborvitae naturally makes a good-sized tree.) While the garden edging thus produced is not so clean and solid as might be desired, it is yet reasonably good and the experiment may be recommended to any patient gardener.

Tsuga canadensis, Canada Hemlock. A well-known native evergreen tree suited to cold lands, and northern exposures. It has long been known as a highly desirable hedge material. It thrives admirably under the shears and makes a smooth, thick, and very beautiful hedge. On the dry warm soil of our experimental planting two trees were lost in the dry summer of 1930; otherwise the hedge has done well. Planted in 1926, it is now 2 feet high and 2 feet broad. This is rather small. A hemlock hedge does its best when 6 feet tall or more, up to 15 feet, or as high as shearing is practicable. Where the soil is moist and cool (drying out of the roots is fatal), the Canada hemlock is unsurpassed for hedge work.

Canada Hemlock always makes a beautiful hedge on proper soil (White Pine on left)

Tsuga caroliniana, Carolina Hemlock. Similar to the foregoing, with foliage slightly lighter green and twig growth more irregular. Even on the light soil of this plantation makes a good stand with an annual growth of 4-10 inches. In 10 years it has never shown dead spots or other indications of weakness. On heavy cool soil even better results might be anticipated. However, there is no reason for using this species in New England in substitution for the native hemlock.

Viburnum cassinoides, Withe-rod. A hardy and beautiful native shrub with good habit of growth, good foliage, rather attractive flowers and fruit. Apparently well adapted for hedge making, especially when very severe shearing is not required. In the present experiment it has never made a good hedge; but the reason lies so obviously in the plants' incompatability with the dry, gravelly soil that some excuse may be granted. The withe-rod is considered well worth further trial on moister, richer soil.

Carolina Hemlock, ten years planted—one of the best of all hedges

WEIGELA EVA RATHKE. A popular garden shrub, hardy, with clean, rather coarse foliage and attractive dark red flowers. This shrub grows well and would seem promising for use as a garden hedge, but this promise has not yet been fulfilled in the college plantings. Plants set in hedge rows in 1926 have not made sufficiently strong and even growth to form a good hedge; but they deserve a more extended trial.

Carolina Hemlock, winter aspect, admired by all beholders

Publication of this Document Approved by Commission on Administration and Finance.
6M-4-'31. No. 1995.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 273 April, 1931

Infectious Trachitis

By Charles S. Gibbs

Infectious trachitis has been the case of heavy losses to the poultry industry in the State of Massachusetts. Evidences are apparent that these losses are increasing, and there is a pronounced interest in methods of prevention and control. This study of the disease, its symptoms, pathology and mode of transmission, was undertaken to furnish a basis for procedure in perfecting control methods.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

INFECTIOUS TRACHITIS

By Charles S. Gibbs

Assistant Research Professor of Veterinary Science

The disease discussed in this bulletin has been given several names by different investigators. The symptoms, pathology, and virulence appear to vary in the different localities from which it has been reported. Hinshaw (1925), after studying the disease at feeding stations in the Middle West, decided to name it infectious bronchitis. May and Tittsler (1925), while studying an outbreak in pullets and cockerels, influenced more or less by extreme cold in the open, called the disease tracheolaryngitis. These names may have been appropriate for the particular strains of infectious trachitis studied, but neither name applies to the thirteen strains included in this investigation.

Ten strains used in these experiments came from widely separated towns in Massachusetts, two from California, and two from New Jersey. Bronchitis was not produced by any of these strains. Laryngitis was less frequent than hepatitis, splenitis, and nephritis. The infection apparently began in the trachea, and the chief lesion was present in and confined to this tract. While a pseudomembrane was quite often found in the larynx, this lesion was not much more common that patches of diphtheritic membrane in the naso-pharynx, esophagus, and commissures of the beak. Laryngitis was a secondary lesion following a primary focal infection in the trachea, and fell into the same category as hepatitis, splenitis, nephritis, and the formation of pseudomembrane and cheesy exudate in the infraorbital and paranasal sinuses. Because some birds died of suffocation, due to an excessive formation of pseudomembrane in the larynx and trachea, the name laryngotrachitis might have been appropriate in such cases. In general a shorter name is preferable. The name infectious trachitis is suggested because it is easily pronounced, includes the prominent lesions of the disease, and differentiates this malady from all other respiratory afflictions of the domestic fowl. Here it will be called infectious trachitis.

Infectious trachitis has not been definitely reported outside of the United States and Canada. Newcastle disease, reported by Doyle (1927) in England, an enzootic discovered by Kee (1928) in the Philippines, and a new affliction of poultry in India called "*Ranikhet*" by Cooper (1929) present some similarities. It may be significant to mention that most of our breeds of poultry came originally from the Orient and England. Kernohan (1930) showed that infectious trachitis has existed in this country for a long time. It may be that the relation of these diseases is closer than is realized at present.

A study of the necropsy records of specimens submitted to the Department of Veterinary Science at the Massachusetts State College for diagnosis shows that infectious trachitis probably was present in Massachusetts as early as March, 1920. A study of the records kept the last six months of 1928, and the years 1929 and 1930, indicates that enzootic centers of infectious trachitis existed in nearly all parts of the

State. While these laboratory records, associated with the diagnostic service, do not give the total number of cases for any period, they show that the disease has existed in Massachusetts for at least ten years, and during this time has been progressively advancing into new territory.

It should be pointed out that the specimens sent to the laboratory were almost entirely from localities in which infectious trachitis had not been reported in previous years. Apparently each specimen represented a new enzootic center, in which the disease was not recognized, and poultrymen took advantage of the laboratory for diagnosis. In this way, it was discovered that at least seven new enzootic centers had developed each year for the last ten years. The mortality observed by reliable poultrymen in individual flocks under field conditions varied from 5 to 90 per cent, depending upon the age, condition, and resistance of the birds.

Sometimes in flocks consisting of pullets and cockerels, the outbreaks were explosive in character; the disease, in such instances, spread through the flocks in a week or two in spite of all efforts to check it, took its toll, which was usually heavy, and disappeared as quickly as it came. In flocks of older birds, such as are commonly kept for breeding purposes, the disease often spread slowly and in such flocks was likely to appear sporadically. In some of the birds the infection was acute, while in others it was chronic. Some of the chronic cases showed lesions of pseudomembrane in the trachea and larynx for five or six months. In these sporadic appearances of infectious trachitis the mortality usually was low, but the loss in production in most instances was great.

External factors, such as cold and damp weather, overcrowding and under-feeding, have been held responsible for predisposing flocks to the disease. While these predisposing factors are important in the propagation of infectious trachitis, the experiments which follow indicate that the disease is caused by a filtrable virus, and that poultry will not contract it unless this causative agent is present.

The First Transfer of Granby Virus.

Two field cases of infectious trachitis were sent to the laboratory for experimental purposes on November 20, 1929. Since the flock of origin was at Granby, Massachusetts, the material was designated the Granby Virus, in order to distinguish it from the strains used in other experiments. The same day the field cases were received, four White Leghorn cockerels, VP 880, VP 881, VP 882, and VP 884, were inoculated intratracheally by means of cotton swabs. White Leghorn cockerel, VP 885, was kept as an uninoculated control. All of the inoculated cockerels developed the disease with the following clinical and pathological histories.

Five days after inoculation, VP 880 appeared listless, ruffled, inappetent, and anemic. Slight dyspnea appeared at inspiration. An examination by transmitted light showed pseudomembrane in the rima glottis. The next day, November 26, the dyspneic symptoms were increased and halitosis was very evident. The bird appeared to be weak and spent most of the time off its feet. The seventh day after inoculation, November 27, the cockerel was unable to stand. At inspiration the head was raised, while the bird gasped for breath with open beak and emitted a peculiar sound as the air was inspired. During expiration the head was

lowered and the beak allowed to rest on the breast for a few moments. The comb and wattles were cyanotic in appearance. The head and legs felt cold to the touch. Since the progress was unfavorable the bird was killed. The general condition of the cockerel was emaciated and anemic. Necropsy revealed patches of yellowish-white pseudomembrane in the pharynx, while the larynx was nearly occluded with a cheesy white mass. The trachea showed desquamative epithelial inflammation and hemorrhages of the mucosa and submucosa. In addition, fatty degeneration of the liver and hemorrhagic inflammation of the tubular tissues of the kidneys were present. Histopathological sections of tissues from the trachea showed desquamation of the epithelium, hemorrhages and coagulation necrosis of the mucosa and submucosa.

Cockerel VP 881 did not show any symptoms of disease for nine days. On November 29, it was not as active as usual, the feathers appeared ruffled, saliva flowed from the beak, and all desire for feed had vanished. The bird was weak, scarcely able to stand, and dyspnea was apparent. Without showing any signs of improvement the cockerel died two days later. The carcass was emaciated. The comb and wattles were cyanotic. Postmortem examination revealed the presence of congestion and pus in the larynx and posterior nares. The trachea was filled with a purulent muco-fibrinous mass, and the mucosa was inflamed and necrotic in places. The lungs were congested and showed consolidated areas near the periphery. Histopathological slides prepared from diseased tissues showed hyperemia and fibrino-purulent inflammation of the trachea and larynx, congestion of the lungs with a large number of small mononuclear leucocytes in the alveolar spaces, cloudy swelling and fatty degeneration of the liver, and cloudy swelling and hemorrhagic inflammation of the tubular areas of the kidneys.

Cockerel VP 882 showed symptoms after six days. On November 26 the bird had no desire for feed, appeared to be weak, the comb and wattles were cyanotic, and there was a pronounced inspiratory dyspnea. The cockerel died the following day. The general condition of the carcass was fair. Necropsy revealed desquamative inflammation of the trachea. The exposed surface of the mucosa appeared dry and of a grayish-yellow color. The syrinx was occluded with dried exudate containing desquamated ciliated epithelium, apparently from the trachea. The lungs, kidneys, liver, and spleen were hemorrhagic in appearance. Histological sections of tissues from the diseased areas, stained by Unna's alkaline methylene blue and eosin, confirmed all of the gross findings.

In addition, the trachea showed hyperemia and fibrinous inflammation of the mucosa and submucosa; the lungs, interstitial inflammation with a tendency toward consolidation at the periphery; the kidneys, cloudy swelling; the liver, perivascular foci of hyperplasia of histiocytes and hydropic degeneration; the spleen, congestion and large number of polymorphonuclear and small mononuclear leucocytes in the arteries, capillaries, and in some places in the parenchyma.

Cockerel VP 884 showed symptoms of disease eight days after inoculation. On November 28 this cockerel did not eat, the feathers appeared ruffled, and the face was pale. The next day dyspnea and emesis were present. The vomiting was apparently caused by fermented feed in the crop. An examination by transmitted light disclosed pseudomembrane

in the rima glottis. The comb and wattles appeared cyanotic. The temperature of the bird was 107° F. On December 2, the temperature was 106.7° F. The cockerel died the following day. The carcass was emaciated and anemic. An examination for gross pathology revealed desquamative epithelial inflammation of the trachea, leaving the mucosa dry and grayish-yellow in color. The syrinx was occluded with dried exudate. Enteritis was marked. The intestinal wall appeared hyperemic and necrotic in places. The tissues of the lungs, liver, and kidneys were hemorrhagic. Histopathological sections revealed fibrinous inflammation of the mucosa and submucosa of the trachea; congestion and hemorrhagic inflammation of the lungs; cloudy swelling, and foci of hyperplasia of histiocytes in the liver; cloudy swelling and hemorrhagic inflammation of the kidneys and spleen. Sections of the lesions in the intestinal wall manifested hyperemia, necrosis, and foci of hyperplasia of reticuloendothelial cells with lymphoid infiltration. Some of the hyperplastic areas showed diffused inflammation.

From this study of infectious trachitis in the four cockerels, it was found that the disease was both infectious and easily transmitted from diseased to healthy birds by intratracheal inoculation. The incubation period and the length of time that the cockerels lived after inoculation with this virus varied as follows:

Cockerel No.	Incubation period	Time from inoculation to death
	Days	*Days*
VP 880	5	7*
VP 881	9	11
VP 882	6	7
VP 884	8	13
Average	7	10.33

* Killed. Omitted from the average.

The uniformity of symptoms and pathological lesions in all four cockerels, following inoculation, demonstrated that the Granby virus was a pure strain of infectious trachitis. The symptoms and pathological lesions were in general typical of the disease as found in all of the birds studied in this investigation.

These studies further indicated that the degenerative changes in the mucosa and submucosa were not severe as long as the epithelium remained intact or was promptly replaced by a pseudomembrane to prevent hemorrhages and secondary microbial infection which often lead to necrosis and suppuration.

The Second Transfer of the Granby Virus.

A White Leghorn cockerel and two Barred Plymouth Rock fowls were inoculated November 27, 1930, with a pooled virus from the tracheas of VP 880 and VP 882 to determine whether this virus could be propagated under laboratory conditions in fowls, since younger birds were not available at this time. The results of these inoculations are reported in Table I.

The Granby virus had retained its potency sufficiently in this second transfer to kill cockerel VP 885 and fowl 30991, and to cause serious illness in fowl 30992.

TABLE 1.—THE SECOND TRANSFER OF THE GRANBY VIRUS.

Date	Cockerel No. VP 885		Fowl No. 30991		Fowl No. 30992	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
11/27/29		Inoculated	107.0	Inoculated	106.9	Inoculated
11/28/29			107.0		107.0	
11/29/29			106.8		106.9	
11/30/29	107.0		107.4		107.0	
12/2/29	107.0	Dyspnea	110.0+	Inspiratory	107.0	
12/3/29		Dead	109.4	dyspnea	107.2	
12/4/29		(Lesions typical of		Dead	107.4	
12/5/29		infectious trachitis)		(Lesions typical of	108.5	Symptoms of
12/6/29				infectious trachitis)	108.5	infectious
					108.2	trachitis
					107.1	
					107.0	Improved
					107.0	Recovered

The Third Transfer of the Granby Virus

Three Rhode Island Red fowls were inoculated intratracheally December 11, 1929, with virus from VP 885 and 30991 in order to continue the propagation of the Granby virus. The results are noted in Table 2.

TABLE 2.—THE THIRD TRANSFER OF THE GRANBY VIRUS.

Date	Fowl No. I 1551		Fowl No. I 1514		Fowl No. I 1698	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
12/11/29	107.7	Inoculated	107.2	Inoculated	107.1	Inoculated
12/12/29	106.7		106.9		107.0	
12/13/29	106.4		106.4		106.2	
12/14/29	106.8		107.0		106.9	
12/16/29	107.7		107.3		107.0	
12/17/29	107.9	Cough	107.2		107.1	
12/18/29	107.9		107.3		107.4	
12/19/29	108.2	Inappetence	107.4		107.1	
12/20/29	108.4	Inspiratory	107.2		107.2	
12/21/29	108.8	dyspnea	107.1		107.1	
12/23/29	107.4	Improved	107.0		106.8	
12/24/29	107.3		106.9		107.2	
12/26/29	107.2		107.3		107.3	
12/27/29	106.5	Recovered	107.2	Unaffected	107.2	Unaffected
12/31/29		Killed	106.9	Killed	107.1	Killed
		(Laryngitis)		(Laryngitis)		(No lesions)

Fowls I 1551 and I 1514 had laryngitis and I 1698 did not show any symptoms or lesions of disease. From these results it was concluded that the virulence of the Granby infectious trachitis virus had attenuated during the third transfer and the resistance of the fowls may have been a factor in the process.

Rhode Island Red fowl MC 60840 contracted the disease from an accidental infection and died December 30, 1929. This made it possible to check up the experiments on the filtration of the Granby virus. Also, a fourth transfer of the Granby virus was made from this fowl, demonstrating that the resistance of fowls I 1551, I 1514, and I 1698 was largely responsible for the attenuation of the Granby virus.

The Fourth Transfer of the Granby Virus

Three Rhode Island Red fowls were treated intratracheally with virus from MC 60840 on January 2, 1930. The results of this transfer of the Granby virus are given in Table 3.

TABLE 3.—THE FOURTH TRANSFER OF THE GRANBY VIRUS.

Date	Fowl No. I 2132		Fowl No. I 2567		Fowl No. I 2106	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
1/2/30	107.2	Inoculated	107.3	Inoculated	107.1	Inoculated
1/3/30	107.4		107.2		107.2	
1/4/30	107.3		107.1		107.1	
1/5/30	107.4		107.3		107.2	
1/6/30	107.5		107.3		107.2	
1/7/30	107.4	Symptoms of	107.4		107.1	
1/9/30	109.0	infectious	107.2		107.0	
1/10/30	110.0+	trachitis	108.5	Symptoms of	109.2	Symptoms of
1/11/30	109.5		109.4	infectious	108.3	infectious
1/12/30	106.4		108.2	trachitis	108.6	trachitis
1/13/30		Dead	107.4		109.2	
1/14/30		(Lesions typical of	107.6	Improved	107.2	Dead
1/16/30		infectious trachitis)	107.4			(Lesions typical of
1/17/30			107.2			infectious trachitis)
1/18/30			107.0	Recovered		

In this experiment the Granby virus was found to be of sufficient virulence to infect all three of the fowls inoculated. Two of the fowls died and one recovered. This experiment demonstrated that the Granby virus had retained its potency in fowl MC 60840. Like all viruses which cause disease in animals, the Granby virus evidently retains its potency as long as it is transmitted in susceptible birds, but tends to lose its virulence in resistant fowls. The fowls reported under the third transfer of the Granby virus were apparently resistant to the disease.

Filtrability of the Granby Virus

The larynx and trachea of both fowls which furnished the Granby virus were triturated in a sterile mortar with sterile physiological saline solution. After permitting the mass to macerate over night in the ice box, the coarser particles were removed by filtering the fluid through sterile gauze. Then the filtrate was divided into four parts. The first part was forced through a sterile Berkefeld W filter, under an extra pressure of 15 to 18 mm. of mercury, as measured by a manometer attached to a water suction pump. The second portion was subjected to an extra pressure of 10 to 12 mm. of mercury to force it through a Berkefeld N filter. The third part readily passed a Berkefeld V filter under an extra pressure of 6 to 8 mm. of mercury. The fourth part was used as an unfiltered control.

Berkefeld W Filtrate

Three Plymouth Rock fowls were inoculated intratracheally on November 28, 1929, with Granby infectious trachitis filtrate which had passed through Berkefeld W filters. On January 2, 1930, the fowls were reinoculated with tracheal exudate from fowl MC 60840. The results are given in Table 4.

The fowls did not contract infectious trachitis when their tracheas were swabbed with the filtrate of Granby virus which had passed through Berkefeld W filters, but all three were afterwards found susceptible to unfiltered Granby virus. Fowl 30005 died rather quickly after symptoms appeared. A postmortem examination was made and not a lesion of any kind could be found either in or on the body. This may have been a toxemic form of infectious trachitis, as reported by Graham (1929). This experiment indicates that the Granby virus did not pass the pores of the Berkefeld W filters in sufficient quantities to cause infectious trachitis in susceptible fowls.

TABLE 4.—RESULTS OF INOCULATION WITH BERKEFELD W FILTRATE OF GRANBY VIRUS.

Date	Fowl No. 30893		Fowl No. 30894		Fowl No. 30005	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
11/28/29	107.1	Inoculated*	107.0	Inoculated*	107.0	Inoculated*
11/29/29	106.6		106.4		106.8	
11/30/29	107.3		106.4		107.1	
12/2/29	106.4		106.8		106.8	
12/3/29	108.0		106.7		108.0	
12/4/29	107.5		107.4		107.5	
12/5/29	107.4		108.4		107.2	
12/6/29	108.2		108.0		108.2	
12/7/29	107.4	No symptoms	107.5	No symptoms	107.4	No symptoms
12/9/29	107.1	of disease	107.3	of disease	107.1	of disease
12/10/29	107.0		107.0		107.0	
12/11/29	107.1		107.0		107.0	
12/12/29	....		....		107.1	
12/13/29	107.3		107.0		107.3	
12/14/29	107.0		107.1		107.0	
12/16/29	107.1		107.0		107.1	
1/2/30	107.0	Inoculated**	107.2	Inoculated**	107.0	Inoculated**
1/3/30	107.2		107.1		107.0	
1/4/30	107.1		107.2		107.1	
1/6/30	107.0		107.0		107.0	
1/7/30	107.1		107.0		107.3	
1/8/30	107.2		106.7		107.1	Symptoms of
1/9/30	107.8	Symptoms of	107.1		108.5	trachitis
1/10/30	107.8	infectious	107.2		108.6	Dead
1/11/30	107.6	trachitis	107.3			(No lesions
1/13/30	108.2		108.0			found)
1/14/30		Dead	108.2			
1/15/30		(Lesions typical of	108.9	Symptoms of		
1/16/30		infectious trachitis)	109.2	infectious		
1/17/30			107.4	trachitis		
1/18/30			106.9			
1/20/30			106.2			
1/21/30				Dead		
				(Lesions typical of		
				infectious trachitis)		

* Berkefeld W filtrate of Granby virus used.
** Unfiltered Granby virus from MC 60840 used.

The Berkefeld N Filtrate

Three Rhode Island Red fowls were treated intratracheally on November 28, 1929, with the Berkefeld N filtrate and the clinical symptoms and pathological lesions noted are shown in Table 5.

The results of this experiment on the filtration of infectious trachitis virus through Berkefeld N filters indicate that the virus is filtrable in small quantities, since one out of three susceptible fowls was successfully inoculated with it.

TABLE 5.—RESULTS OF INOCULATION WITH BERKEFELD N FILTRATE OF GRANBY VIRUS.

Date	Fowl No. I 2310		Fowl No. I 2436		Fowl No. I 2347	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
11/28/29	107.9	Inoculated*	106.7	Inoculated*	107.0	Inoculated*
11/30/29	107.1		107.0		106.7	
12/2/29	107.3		....		107.1	
12/3/29	108.2		107.2		107.6	
12/4/29	108.4		107.1		107.4	
12/5/29	108.4	Symptoms of	107.1		107.5	
12/6/29	108.2	infectious	107.2		107.3	
12/7/29	106.3	trachitis	107.0		107.4	
12/9/29		Dead	107.1	No symptoms	107.0	No symptoms
12/10/29		(Lesions typical of	107.2	of disease	106.8	of disease
12/11/29		infectious trachitis)	107.3		107.1	
12/12/29			107.2		107.0	
12/13/29			106.8		106.9	
12/14/29			107.2		107.4	
12/16/29			107.0		107.6	
12/17/29			107.0		....	
1/2/30			107.5	Inoculated**	107.5	Inoculated**
1/3/30			107.2		107.3	
1/4/30			107.0		107.4	
1/6/30			106.9		107.2	
1/7/30			107.1		107.0	
1/8/30			107.1		106.8	
1/9/30			107.2		107.1	
1/10/30			107.7		107.2	
1/11/30			110.4	Symptoms of	107.3	
1/13/30			108.4	infectious	107.4	
1/14/30			107.5	trachitis	107.6	
1/15/30			107.7		107.6	
1/16/30			107.1		107.6	Symptoms of
1/17/30			107.2	Recovered	107.2	infectious
1/18/30			107.0	Killed	107.2	trachitis
1/20/30				(Lesions of laryngitis)	107.0	
1/21/30					....	Improved
1/22/30					107.1	
1/23/30					107.5	Recovered
1/24/30					107.3	Killed
					(Lesions of trachitis)	

* Berkefeld N Filtrate of Granby virus used.
** Unfiltered Granby virus from MC 60840 used.

The Berkefeld V Filtrate

The third part of the Granby virus which had been filtered through Berkefeld V candles was used to inoculate three Rhode Island Red fowls intratracheally. The results are recorded in Table 6.

The virus of infectious trachitis passed the Berkefeld V filters in sufficient quantities to inoculate I 1168 and 30999. However, the filtrate had no effect upon I 1515, which was also found immune to the MC 60840 virus.

TABLE 6.—RESULTS OF INOCULATION WITH BERKEFELD V FILTRATE OF GRANBY VIRUS.

Date	Fowl No. I 1168		Fowl No. I 1515		Fowl No. 30999	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
11/29/29	106.4	Inoculated*	107.0	Inoculated*	107.0	Inoculated*
11/30/29	106.0		107.4		107.1	
12/2/29	107.2		107.4		107.2	
12/3/29	107.3		107.2		107.0	
12/4/29	107.2		107.1		106.8	
12/5/29	107.3		107.4		107.2	
12/6/29	107.2		107.0		107.3	
12/7/29	107.3		107.4		107.4	
12/9/29	107.3	Symptoms of	107.1		107.8	Symptoms of
12/10/29	107.8	infectious	107.3		108.9	infectious
12/11/29	107.8	trachitis	107.2		107.7	trachitis
12/12/29	107.2		107.0		107.6	
12/13/29	108.0		106.8		107.2	
12/14/29	107.0		106.5		....	
12/16/29	108.0		106.4		107.6	
12/17/29	109.0		....		....	
12/18/29	106.0		107.4		....	
12/19/29		Dead	107.0		106.7	
12/20/29	(The inflamed mucosa		107.4		106.2	
12/21/29	of the trachea was		107.0			Dead
1/2/30	covered with a film		107.1	Inoculated**		(Pseudomembrane
1/3/30	of blood)		107.3			was not present in
1/4/30			107.2			the respiratory
1/6/30			107.2			tract)
1/7/30			106.8			
1/8/30			106.5			
1/9/30			106.8			
1/10/30			106.9			
1/11/30			106.8	No symptoms		
1/13/30			106.8	of infectious		
1/14/30			106.8	trachitis		
1/15/30			106.8			
1/16/30			107.0			

* Berkefeld V Filtrate of Granby virus used.

** Unfiltered Granby virus from MC 60840 used.

The Unfiltered Granby Virus

A Rhode Island Red fowl and two Plymouth Rock fowls were inoculated intratracheally with the unfiltered portion of the Granby virus suspended in physiological saline solution. The results of this experiment are recorded in Table 7.

This experiment indicates that the unfiltered Granby virus was more virulent than any of the filtered portions.

TABLE 7.—RESULTS OF INOCULATION WITH UNFILTERED GRANBY VIRUS.

Date	Fowl No. I 2188		Fowl No. 30003		Fowl No. 30004	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
11/29/29	107.1	Inoculated	107.1	Inoculated	107.0	Inoculated
11/30/29	107.1		107.1		107.0	
12/2/29	106.8		107.0		107.2	
12/3/29	107.0		106.9		107.3	
12/4/29	108.4	Symptoms of	107.2		107.4	
12/5/29	109.8	infectious	108.2	Symptoms of	107.8	
12/6/29	110.0+	trachitis	109.7	infectious	109.8	Symptoms of
12/9/29		Dead	110.0+	trachitis	110.0+	infectious
12/10/29		(Lesions typical of	109.6		109.5	trachitis
12/11/29		infectious trachitis)	109.4		109.5	
12/12/29			108.2		109.0	
12/13/29			106.4		107.2	
12/14/29			106.0		106.4	
12/16/29				Dead (Lesions typical of infectious trachitis)		Dead (Lesions typical of infectious trachitis)

Controls on Experiments with Granby Virus

White Leghorn fowl 30996 and Plymouth Rock fowls 30997 and 30998 were controls on all of the fowls on the Granby virus experiments, beginning with the second transfer of the virus on November 27, 1929. A record of the experiments with the controls appears in Table 8.

The controls indicate that cross infections did not occur in the experiments on the Granby virus. All of the controls were later found to be susceptible to infectious trachitis.

Experiments with Chronic Field Cases Under Laboratory Conditions

During the winter of 1929-30, fowls sick with diseases simulating the Granby outbreak of infectious trachitis, were received from the following places in Massachusetts:—Leverett, Westwood, Gardner, South Lincoln, and Watertown. In all of these cases the disease was running a chronic course in laying fowls. Viruses from these birds produced either chronic symptoms or no indications of disease when fowls and chickens were inoculated intratracheally under laboratory conditions. The results were not always as clear-cut as with the Granby virus. The mortality was low. It was impossible to transmit any of these viruses in the laboratory in a satisfactory manner. Most of the time the temperatures of the inoculated birds were normal. The most common symptoms were lacrimation of the eyes, cough, and pseudomembrane in the larynx. None of the birds ceased to eat. Some of the fowls continued to lay during the

TABLE 8.—HISTORY OF BIRDS USED AS CONTROLS ON THE GRANBY VIRUS EXPERIMENTS.

Date	Fowl No. 30996		Fowl No. 30997		Fowl No. 30998	
	Temp.	History	Temp.	History	Temp.	History
	°F		°F		°F	
11/27/29	107.0		107.3		107.1	
11/29/29	106.8		107.2		107.3	
11/30/29	107.1		107.3		107.0	
12/2/29	107.2		107.3		107.0	
12/3/29	107.2		107.0		107.4	
12/4/29	107.0		107.2	No symptoms	107.2	No symptoms
12/5/29	107.1	No symptoms	....	of disease	107.1	of disease
12/6/29	107.0	of disease	107.1		107.0	
12/7/29	107.2		107.3		107.2	
12/9/29	107.2		107.1		107.0	
12/10/29	107.0		106.9		107.2	
12/11/29	107.3		107.0		107.1	
12/12/29	107.0		107.2		107.3	
12/13/29	106.9		107.1		107.2	
12/14/29	107.0		107.2		107.1	
12/16/29	107.2	Inoculated*	106.9	Inoculated*	107.0	Inoculated*
1/2/30	106.7		107.0		106.8	
1/3/30	107.0		107.1		107.0	
1/4/30	107.2		107.4		107.1	
1/6/30	106.2		107.3		107.5	
1/7/30	106.8		107.9		107.4	
1/8/30	108.6		107.0		107.4	
1/9/30	107.3		107.0	Symptoms of	107.2	
1/10/30	107.0		107.4	infectious	107.6	Symptoms of
1/11/30	107.0	Symptoms of	107.3	trachitis	107.5	infectious
1/13/30	107.4	infectious	107.3		107.5	trachitis
1/14/30	107.9	trachitis	....	Recovered	107.2	
1/15/30	108.0				....	Recovered
1/16/30	108.1					
1/17/30	108.2					
1/18/30	107.7					
1/20/30	107.2					
1/21/30	107.4	Killed (Lesions typical of infectious trachitis. Tapeworms and caecal worms present.)				

* Virus from MC 60840 used.

experiments, showing that the viruses were not especially virulent. Attempts to enhance the virulence of these viruses by continuous passages through fowls and chickens failed. For reasons not well understood, these viruses tended to weaken in continuous passage under laboratory conditions. The results of typical experiments with Leverett, Westwood, Gardner, South Lincoln, and Watertown chronic field cases of infectious trachitis are recorded in Tables 9 and 10.

The Leverett virus killed four of the seven pullets which contracted

the disease in the flock at Leverett. The fact that these seven birds were brought to the Laboratory of Veterinary Science at Amherst and given the best of individual care made little difference in mortality, as compared with the flock as a whole. When an attempt was made to transmit the disease to pullets of the same age from another source, only one

TABLE 9.—THE FIRST TRANSFER OF VIRUS FROM CHRONIC FIELD CASES.

Treatment	Date	Bird No.	Effect	Final result	Date
Inoculated with Leverett virus	1/13/30	Pullet			
	1/27/30	L 31	None	Unaffected	
	1/27/30	L 32	None	Unaffected	
	1/17/30	L 33	None	Unaffected	
		L 34	Acute	Dead	
Inoculated with Westwood virus	2/26/30	Fowl			
		ME 38548	None	Unaffected	3/3/30
		ME 38450	None	Unaffected	3/3/30
		ME 38702	None	Unaffected	3/3/30
		ME 38704	None	Unaffected	3/3/30
		ME 38718	None	Unaffected	3/3/30
		ME 38677	Mild	Recovered	3/7/30
		ME 38177	Mild	Recovered	3/3/30
		ME 38489	Mild	Recovered	3/7/30
		ME 38647	Mild	Recovered	3/11/30
	5/15/30	Cockerel			
		Bel. 1	Mild	Recovered	Undetermined
		Bel. 2	Mild	Recovered	Undetermined
		Bel. 3	Mild	Recovered	7/5/30
		Pullet			
		Bel. 4	Mild	Recovered	6/5/30
		Bel. 5	Mild	Recovered	Undetermined
		Bel. 6	Mild	Recovered	Undetermined
Inoculated with Gardner virus	3/15/30	Cockerel			
		MA 94476	Mild	Recovered	4/7/30
		MA 94480	Mild	Recovered	Undetermined
		MA 94465	None	Unaffected	4/1/30
		MA 94479	Acute	Recovered	4/7/30
		Pullet			
		MA 94468	Acute	Recovered	4/15/30
		MA 94470	Acute	Dead	3/27/30
		MA 94464	Mild	Recovered	4/7/30
		MA 94472	None	Unaffected	4/1/30
		MA 94481	None	Unaffected	4/1/30
		MA 94424	None	Unaffected	4/1/30
Inoculated with So. Lincoln virus	4/30/30	Fowl			
		ME 38750	None	Unaffected	5/13/30
		ME 38540	None	Unaffected	5/13/30
		Cockerel			
		MA 94475	None	Unaffected	5/13/30
		MA 94466	None	Unaffected	5/14/30
		MA 94467	None	Unaffected	5/14/30
		Chicken			
		V 2201	None	Unaffected	5/14/30
		V 2202	None	Unaffected	5/14/30
		V 2203	None	Unaffected	5/14/30
Watertown virus*	5/20/30	Chicken			
		VR 1	None	Unaffected	6/7/30
		VR 2	None	Unaffected	6/7/30
		VR 3	None	Unaffected	6/3/30
		VR 4	None	Unaffected	6/7/30
		VR 5	None	Unaffected	6/7/30
		V 2213	None	Unaffected	6/7/30
		V 2214	None	Unaffected	6/7/30

* VR 1, VR 2, and VR 3 were inoculated with exudate from the trachea of one of the Watertown fowls; VR 4 and VR 5 were placed in a cage with another Watertown bird and kept for a month, until the fowls had completely recovered from the disease; V 2213 and V 2214 were fed the trachea, lungs, spleen, liver, and kidneys of a third fowl showing lesions of infectious trachitis.

of the four pullets so treated contracted the disease and died. The results of this transfer appear in Table 9. An attempt to inoculate chicken MA 94420 with virus from chicken L 34, as recorded in Table 10, was futile, for MA 94420 did not take the disease. The Leverett infectious trachitis virus tended to produce a chronic form of the disease which was not easily transmitted to healthy chickens under laboratory conditions.

Two attempts were made to transmit Westwood virus. In the first experiment nine healthy fowls were inoculated on February 26, 1930, with tracheal exudate from two Westwood fowls showing clinical symptoms of infectious trachitis. Four of the inoculated birds developed mild, nonfatal cases, and five did not react at all.

The next chronic field virus tried out in the laboratory came from Gardner on March 15, 1930. An attempt was made to transmit the infection to healthy birds under laboratory conditions. With this object in view, four cockerels and six pullets were treated intratracheally with exudate from the tracheas of the fowls sent in. Also the livers, spleens, and kidneys showing lesions of infectious trachitis were fed to the cockerels and pullets. Table 9 shows that four of the birds remained well throughout the experiment, three had mild chronic cases with cough and pseudomembrane in the larynx, and three developed acute symptoms of disease. One of these three, MA 94470, died.

An attempt to transfer the disease from the three acute cases is recorded in Table 10. There were no fatal results, although chicken MA 94473 contracted the disease in a mild form. The final virus was lost in an attempt to transfer it from MA 94473 to MA 94469.

Three fowls having chronic infectious trachitis were sent in from South Lincoln on April 30, 1930. Two fowls, three cockerels, and three young chickens were treated intratracheally with this virus and no reactions occurred. The virus had apparently lost its virulence, although the fowls sent to the laboratory were suffering from severe chronic types of infectious trachitis.

The last infectious trachitis virus mentioned in Table 9 was called the Watertown virus because it was found in a flock of laying hens at Watertown. Seven chickens about a month old were placed on this experiment. All of the chickens remained well, demonstrating once more that it was not always possible to successfully inoculate healthy birds with infectious trachitis virus from old chronic cases of the disease.

TABLE 10.—THE SECOND TRANSFER OF VIRUS FROM CHRONIC FIELD CASES.

Virus	Transferred			Result
	From	To	Date	
Leverett	L 34	MA 94420	1/27/30	None
Gardner	MA 94479	MA 94477	3/22/30	None
	MA 94468	MA 94482	3/28/30	None
	MA 94470	MA 94473	3/28/30	Mild

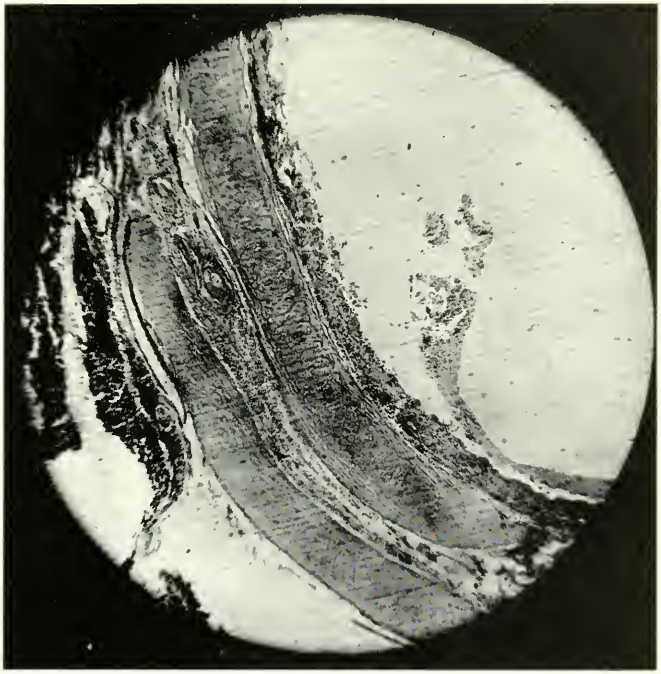


Fig. 1.—Desquamative Epithelial Inflammation of the Trachea of Cockerel 881. (Magnification 420 diameters.)

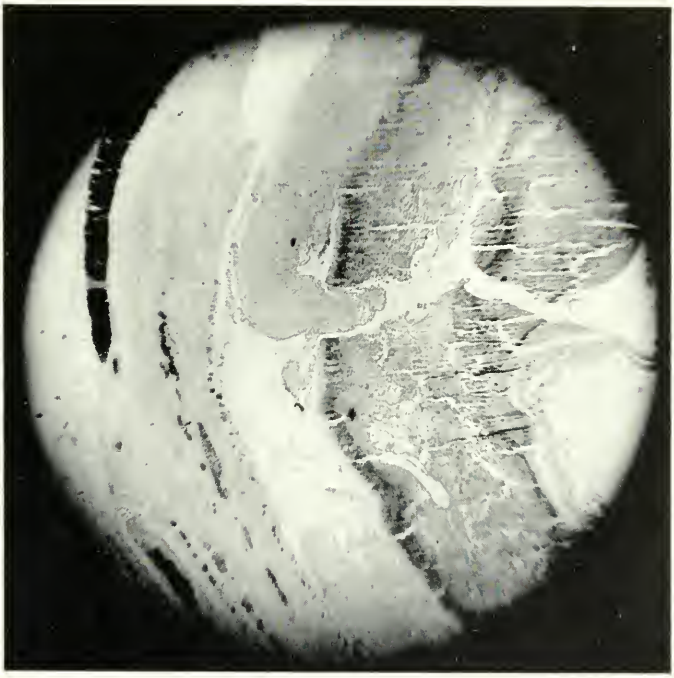


Fig. 2.—Pseudomembrane in the Trachea of Chicken MA 94479. (Magnification 200 diameters.)

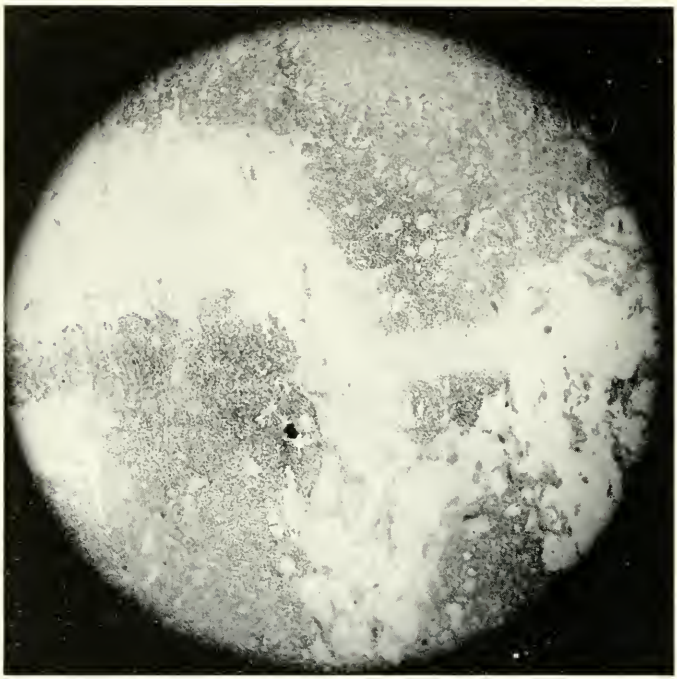


Fig. 3.—Interstitial Inflammation of the Lung of Cockerel 882. (Magnification 420 diameters)

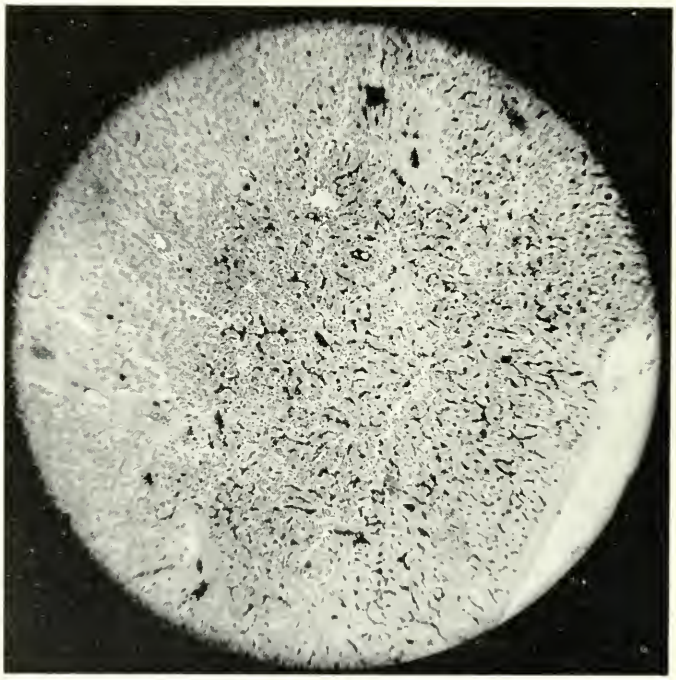


Fig. 4.—Hemorrhagic Inflammation and Coagulation Necrosis of the Liver of Fowl 60553. (Magnification 420 diameters.)

Fig. 5.—Fatty Degeneration of the Liver of Cockerel 884.
(Magnification 420 diameters.)

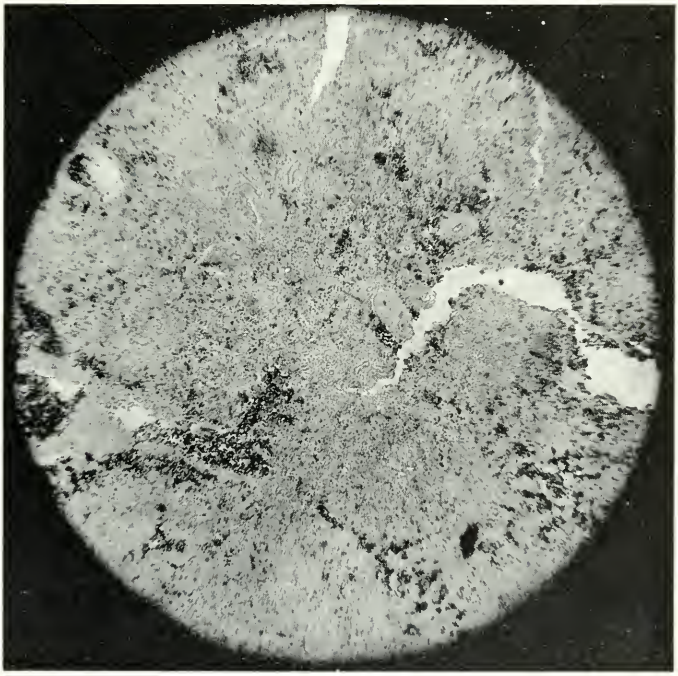


Fig. 6.—Ruptures and Hemorrhages in the Spleen of Cockerel 882.
(Magnification 420 diameters.)

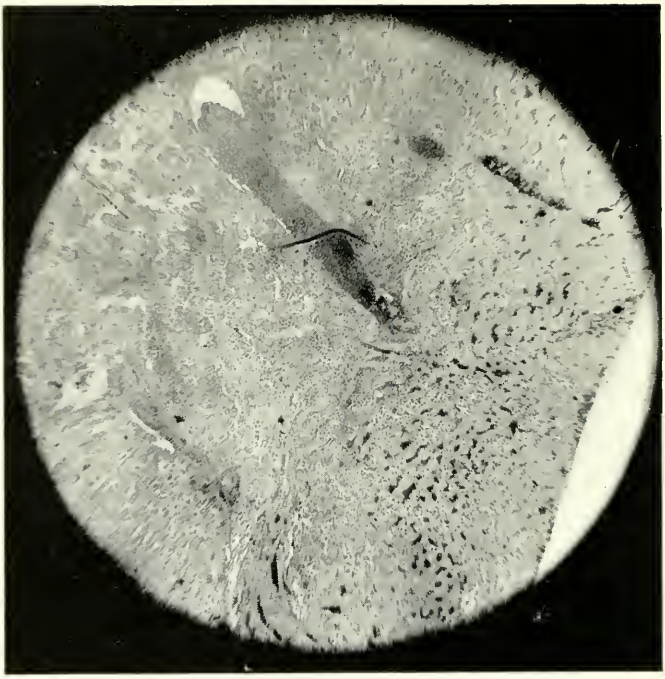


Fig. 7.—Hemorrhages in Cortical Substance of Kidney of Chicken V 2244. (Magnification 420 diameters.)

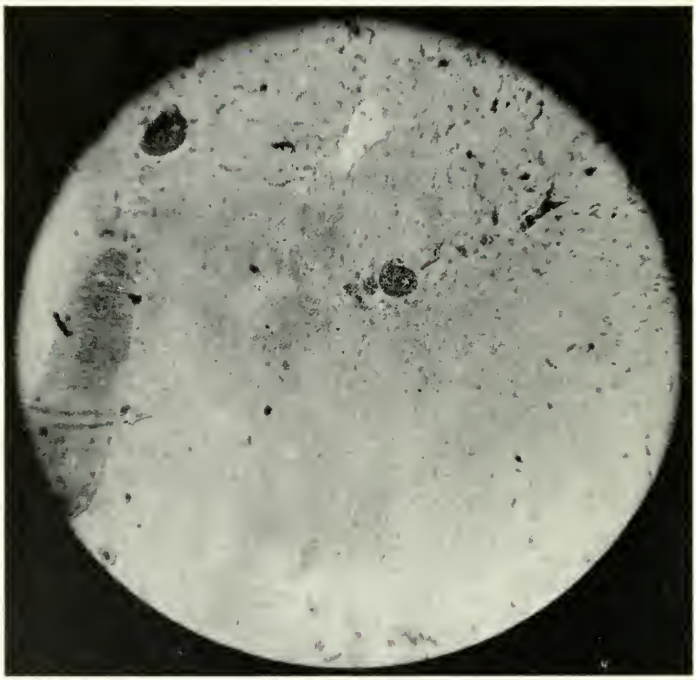


Fig. 8.—Hemorrhagic Inflammation and Coagulation Necrosis Extending into the Medullary Substance of Kidney of Chicken V 2241. (Magnification 420 diameters.)

Continuous Passage of the First California Virus

In order to make comparative studies of infectious trachitis from different parts of the United States, outside of Massachusetts, two strains were obtained from California in the spring of 1930. Since these viruses came in the hatching season, it was possible to use chickens in the experiments. It was anticipated from the results secured with the Granby virus and others that chickens would be less resistant than fowls, so that the virulence could be more uniformly maintained. Chickens between one and three months of age were used in these experiments. Results are shown in Table 11.

TABLE 11.—TRANSFERS OF FIRST CALIFORNIA VIRUS.

Transfer				Termination	
Number	Date	Chicken	Method	Date	Result
First	5/23/30	MA 30892	Intratracheal	6/2/30	Killed
Second	6/2/30	V 2215	Intratracheal	6/10/30	Dead
Third	6/10/30	V 2219	Intratracheal	6/16/30	Dead
Fourth	6/16/30	V 2207	Intratracheal	6/23/30	Dead
Fifth	6/23/30	MA 94479	Intratracheal	6/28/30	Dead
Sixth	7/1/30	V 2220	Intratracheal	7/9/30	Dead
Seventh	7/9/30	V 2230	Intratracheal	7/18/30	Dead

Plymouth Rock pullet MA 30892.—The first symptoms of infectious trachitis appeared on May 29. However, the resistance of the pullet was marked, and possibly it would have recovered if it had not been killed on June 2 for virus. At necropsy the comb was cyanotic, the face pale, the feathers ruffled, but there were no indications of anemia or inanition. The lungs and trachea were congested. There was no evidence of pseudomembrane in the respiratory tract. Petechiae were evident in the mucosa of the trachea. The spleen was inflamed and enlarged. The liver showed fatty degeneration and hemorrhagic inflammation. The case was diagnosed as infectious trachitis.

Chicken V 2215.—A postmortem examination revealed desquamative epithelial inflammation of the trachea and congestion of the lungs, but pseudomembrane was absent from the respiratory tract.

Chicken V 2219.—The face was pale, the comb cyanotic, the trachea congested and inflamed without pseudomembrane. The internal organs were apparently normal except the kidneys, which were somewhat hemorrhagic.

Chicken V 2207.—The general condition of the bird was fair. A postmortem examination showed desquamative epithelial inflammation of the trachea with patches of pseudomembrane in the posterior nares, pharynx, and larynx. The mucous membrane of the trachea was moist, and petechiae were visible in the mucosa beneath the epithelium. The lungs were congested. There was fatty degeneration of the liver. This was the first instance in which pseudomembrane was associated with the California virus

in our hands.

Chicken V 2230.—At necropsy, the general condition was good. The face was pale and the comb cyanotic. Pseudomembrane was found in the larynx, the trachea was inflamed, and congestion was noticed in the lungs, but no evidence of consolidation could be found. The kidneys were swollen and the tubular areas were hemorrhagic.

V 2230 culminated one month and twenty-five days of successful transmission of the California virus in the laboratory without loss of virulence. The average period of incubation in these chickens was five days, the longest seven days, and the shortest three days. The average fatal course after inoculation with the first California virus was 7.57 days, the longest 10 days, and the shortest 5 days.

Continuous Passage of the Second California Virus

The second California virus was propagated at the same time as the first virus. The results were nearly alike and the data for the second virus are given in Table 12.

TABLE 12.—TRANSFERS OF SECOND CALIFORNIA VIRUS.

Transfer				Termination	
Number	Date	Chicken	Method	Date	Result
First	5/23/30	MA 94465	Intratracheal	5/29/30	Killed
Second	5/29/30	V 2205	Intratracheal	6/2/30	Dead
Third	6/3/30	V 2211	Intratracheal	6/6/30	Dead
Fourth	6/7/30	V 2214	Intratracheal	6/10/30	Dead
Fifth	6/10/30	V 2221	Intratracheal	6/16/30	Dead
Sixth	6/16/30	V 2217	Intratracheal	6/19/30	Dead
Seventh	6/23/30	V 2232	Intratracheal	7/1/30	Dead

The second California virus was transmitted in series, through seven chickens from one to three months of age, covering a period of one month and eight days, without losing in virulence. The average fatal course after inoculation with the second California virus was 4.71 days; the shortest, 3 days; and the longest, 8 days.

The Immunological Specificity of Infectious Trachitis

On June 23, 1930, two chickens, six fowls, seven pullets, and seven cockerels which had survived inoculations of Granby, Gardner, Westwood, Hadley, South Lincoln, and Watertown strains, were inoculated intratracheally with California virus from V 2207. The results of this experiment are reported in Table 13.

In view of the great variation in immunity among the strains of infectious trachitis used in this experiment, it can not be stated that the immunity produced by any strain is specific for the California virus. How-

ever, the foregoing conclusion is drawn with all reserves because of the limited number of strains studied, and the data upon which it is founded are given in Table 13 so that its limitation may be readily appreciated.

TABLE 13.—A COMPARATIVE IMMUNOLOGICAL STUDY OF INFECTIOUS TRACHITIS

Bird		First Inoculation			Second Inoculation (California virus 6/23/30) Result
Number	Kind	Virus	Date	Result	
I 2567	Fowl	Granby	1/2/30	Recovered	Unaffected
I 1132			12/3/29	Unaffected	Unaffected
I 1567			12/3/29	Recovered	Unaffected
ME 38677	Fowl	Westwood	2/26/30	Recovered	Unaffected
ME 38548			2/26/30	Unaffected	Unaffected
ME 38713	Fowl	Hadley	1/22/30	Acute	Unaffected
MA 94468	Pullet	Gardner	3/15/30	Acute	Unaffected
MA 94464			3/15/30	Mild	Dead
MA 94473			3/28/30	Mild	Unaffected
MA 94476	Cockerel		3/15/30	Mild	Affected
MA 94480			3/15/30	Mild	Unaffected
MA 94472	Pullet		3/15/30	Unaffected	Unaffected
MA 94481			3/15/30	Unaffected	Unaffected
MA 94479	Cockerel		3/15/30	Unaffected	Dead
MA 94469	Pullet		4/4/30	Unaffected	Dead
MA 94482			3/28/30	Unaffected	Affected
MA 94424	Cockerel		3/15/30	Unaffected	Affected
MA 94465			3/15/30	Unaffected	Unaffected
MA 94477			3/22/30	Unaffected	Unaffected
MA 94466	Cockerel	So. Lincoln	4/5/30	Unaffected	Unaffected
V 2213	Chicken	Watertown	5/20/30	Unaffected	Dead
V 2214			5/20/30	Unaffected	Dead
V 2202 (Control)	Chicken	Uninoculated	.....	Healthy	Dead

The Filtrability of the First California Virus

The larynx and trachea of four chickens, V 2215, V 2219, V 2207, and MA 94479, were used to prepare three Berkefeld filtrates and one unfiltered suspension of infectious trachitis virus, according to the method described under the filtration of the Granby virus. The results of these filtration experiments appear in Tables 14, 15, 16, and 17.

These experiments indicate that the first California virus did not pass through the pores of Berkefeld W filter in sufficient quantities to infect the three chickens inoculated intratracheally with the filtrate. Sufficient virus passed through the pores of the Berkefeld N filters to infect two chickens; one did not contract the disease, although it was later found susceptible. All three of the chickens inoculated with filtrates from the Berkefeld V filters succumbed. The controls, inoculated with the unfiltered portion of the suspended exudate in physiological saline solution, contracted infectious trachitis and died.

TABLE 14.—RESULTS OF INOCULATION WITH BERKEFELD W FILTRATE OF THE FIRST CALIFORNIA VIRUS.

Date	Chicken No. V 2222	Chicken No. V 2223	Chicken No. V 2224
6/28/30	Inoculated*	Inoculated*	Inoculated*
	No symptoms of disease	No symptoms of disease	No symptoms of disease
7/8/30	Inoculated**	Inoculated**	Inoculated**
7/11/30	Symptoms of		
7/12/30	infectious trachitis	Symptoms of	Symptoms of
7/14/30	Dead	infectious trachitis	infectious trachitis
7/16/30	(Lesions typical of	Dead	
7/17/30	infectious trachitis)	(Lesions typical of infectious trachitis)	Dead (Lesions typical of infectious trachitis)

* Berkefeld W Filtrate of the first California virus used.
** Virus from V 2230 used.

TABLE 15.—RESULTS OF INOCULATION WITH BERKEFELD N FILTRATE OF THE FIRST CALIFORNIA VIRUS.

Date	Chicken No. V 2227	Chicken No. V 2228	Chicken No. V 2229
6/29/30	Inoculated*	Inoculated*	Inoculated*
7/1/30	Symptoms of infectious trachitis		
7/5/30	Dead (Lesions typical of infectious trachitis)	Symptoms of infectious trachitis	No symptoms of disease
7/8/30			Inoculated**
7/12/30		Improved	Symptoms of infectious trachitis
7/14/30		Recovered	Dead (Lesions typical of infectious trachitis)

* Berkefeld N Filtrate of the first California virus used.
** Virus from V 2230 used.

TABLE 16.—RESULTS OF INOCULATION WITH BERKEFELD V FILTRATE OF THE FIRST CALIFORNIA VIRUS.

Date	Chicken No. V 2200	Chicken No. V 2389	Chicken No. V 2390
6/28/30	Inoculated	Inoculated	Inoculated
7/2/30		Symptoms of	Symptoms of
7/5/30	Symptoms of	infectious trachitis	infectious trachitis
7/8/30	infectious trachitis		Dead
7/9/30		Dead	(Lesions typical of
7/12/30	Dead (Lesions typical of infectious trachitis)	(Lesions typical of infectious trachitis)	infectious trachitis)

TABLE 17.—RESULTS OF INOCULATION WITH THE FIRST CALIFORNIA VIRUS UNFILTERED.

Date	Chicken No. V 2231	Chicken No. V 2233	Chicken No. V 2388
6/28/30	Inoculated	Inoculated	Inoculated
7/1/30	Symptoms of		Symptoms of
7/2/30	infectious trachitis	Symptoms of infectious trachitis	infectious trachitis
7/7/30	Dead	Dead	
7/9/30	(Lesions typical of infectious trachitis)	(Lesions typical of infectious trachitis)	Dead (Lesions typical of infectious trachitis)

The Filtrability of the Second California Virus

Tracheal exudate from chickens V 2205 and V 2211 was used to prepare Berkefeld W, N, and V filtrates according to the method reported previously in these experiments. Chickens were inoculated intratracheally with these filtrates and the results noted in Tables 18, 19, and 20.

TABLE 18.—RESULTS OF INOCULATION WITH BERKEFELD W FILTRATE OF THE SECOND CALIFORNIA VIRUS.

Date	Chicken No. V 2204	Chicken No. V 2206
6/3/30	Inoculated* No symptoms of disease	Inoculated* No symptoms of disease
6/16/30	Inoculated**	Inoculated**
6/20/30	Dead (Lesions of infectious trachitis)	Dead (Lesions of infectious trachitis)

* Berkefeld W Filtrate of the second California virus used.
** Virus from Chicken V 2211 used.

TABLE 19.—RESULTS OF INOCULATION WITH BERKEFELD N FILTRATE OF THE SECOND CALIFORNIA VIRUS.

Date	Chicken No. V 2385	Chicken No. V 2386	Chicken No. V 2387
6/3/30	Inoculated* No symptoms of disease	Inoculated* No symptoms of disease	Inoculated* No symptoms of disease
7/1/30	Inoculated**	Inoculated**	Inoculated**
7/5/30	Dead	Dead	
7/16/30	(Lesions of infectious trachitis)	(Lesions of infectious trachitis)	Dead (Lesions of infectious trachitis)

* Berkefeld N Filtrate of the second California virus used.
** Virus from Chicken V 2232 used.

TABLE 20.—RESULTS OF INOCULATION WITH BERKEFELD V FILTRATE OF THE SECOND CALIFORNIA VIRUS.

Date	Chicken No. V 2208	Chicken No. V 2209	Chicken No. V 2210
6/3/30	Inoculated	Inoculated	Inoculated
6/7/30	Symptoms of infectious trachitis		
6/9/30			Symptoms of infectious trachitis
6/11/30	Dead		
6/14/30	(No lesions)	Symptoms of infectious trachitis	
6/18/30			Dead
6/21/30		Dead (Lesions of infectious trachitis)	(Lesions of infectious trachitis)

These experiments demonstrate that the second California virus did not pass the pores of Berkefeld W and N filters in sufficient quantities to infect the five chickens inoculated, although the birds were all found susceptible to the unfiltered virus later. Sufficient virus passed the pores of the Berkefeld V filters to kill the three chickens inoculated, thus indicating that the second California virus was filtrable. Attention should be called to V 2208, as this is the second bird observed in these experiments, apparently dying of infectious trachitis, but showing no lesions of disease.

Demonstration of the Second California Virus in the Tissues of Diseased Chickens

Since the tissues of the spleens, livers, and kidneys of so many of the birds examined at necropsy showed lesions, such as hemorrhagic inflammation, hyperemia, coagulation necrosis, infiltrations, hyperplasia, and fatty degeneration, it was thought that tissues from these organs might yield virus for inoculation purposes. Up to this point tracheal exudate had been depended upon as a source of virus. The supply of tracheal exudate was limited in each case. The need for a greater supply, as well as a more potent virus, was keenly felt as these experiments progressed.

In order to demonstrate the presence of virus in the tissues of chickens dead of infectious trachitis, the following experiments were conducted using the second California virus as the infecting agent:

The liver from V 2211 was triturated in a sterile mortar, with a sterile pestle, in enough sterile saline solution to make a suspension. After remaining in the ice box over night, the liquid was poured through a sterile gauze. This gauze filtrate was run through a Berkefeld V filter. On June 7, 1930, the clear Berkfeld V filtrate was used to swab the tracheas of chickens V 2216 and V 2218. On June 12, V 2216 died of infectious trachitis, but V 2218 remained apparently unaffected. On June 16, V 2218 was re-inoculated intratracheally with unfiltered virus from V 2221 which had just died of infectious trachitis. Five days later V 2218 died of the same disease, showing that it was not immune. This experiment demonstrated that the virus of infectious trachitis was present in the

liver of chicken V 2211 in sufficient potency to withstand dilution and candle filtration, and transmit the disease to one of two healthy chickens following intratracheal inoculation.

Also the Berkefeld V filtrate of the spleen of chicken V 2211 was used to swab the trachea of chicken V 2213. Five days later this chicken died. The general condition of V 2213 was fair. The mucosa of the trachea was inflamed. Coagulation necrosis was evident in some of the histological sections prepared from the tissues of the trachea. Hyperplasia of histiocytes and infiltrations of vascular cells were evident in others. The most important gross lesions were the occlusion of the syrinx with tracheal exudate, congestion, and hyperemia of the lungs, liver, and kidneys. The spleen was about one-half the normal size for a chicken of two months. This is the second time that this anomaly has been observed during the course of this study in birds dead of infectious trachitis.

The spleens of V 2213 and V 2216 were used to prepare a Berkefeld V filtrate. On June 13, 1930, V 2327 was inoculated intratracheally with this filtrate and five days later was found dead in the coop. The carcass showed no evidence of emaciation, although the face was pale, the comb cyanotic, and the feathers ruffled. Apparently the chicken had died of suffocation. Pseudomembrane was found in the anterior trachea and desquamative epithelial inflammation was noted in the posterior trachea. The syrinx was obstructed with tracheal exudate, the lungs were congested, the liver was swollen and hemorrhagic in places, the spleen was inflamed, the kidneys were hemorrhagic in the region of the uriniferous tubules, while the interstitial tissues appeared blanched and anemic. The chicken had died of acute infectious trachitis.

The swollen and hemorrhagic portions of the kidneys of V2213 and V 2216 were carefully dissected out from the normal tissue and used to prepare a Berkefeld V filtrate. On June 13, 1930, the kidney filtrate was used to inoculate chickens V 2225 and V 2226, intratracheally, by means of cotton swabs. A week later V 2226 died. The clinical and pathological findings indicated that the chicken had died of infectious trachitis. Ten days after inoculation V 2225 died. The symptoms and lesions were typical of infectious trachitis and resembled the findings as recorded for V 2213.

Berkefeld V filtrates, prepared from the tracheal exudate of chickens V 2225 and V 2226, were injected intraperitoneally into chicken V 2234 and subcutaneously into chicken V 2235 on June 23, 1930.

Chicken V 2234 died on July 4, 1930. At necropsy the trachea was found congested and hemorrhagic. Patches of pseudomembrane were observed in the respiratory tract. There was fatty degeneration of the liver, the spleen was swollen, the kidneys were hemorrhagic and covered with urates. From these lesions a diagnosis of infectious trachitis was made.

Chicken V 2235 lived until August 8, 1930—one month and four days. In the meantime, the bird had chronic infectious trachitis, the symptoms of which were not serious until August 5. On this day the condition of the chicken was decidedly worse; the face was pale, the feathers ruffled, the appetite failed, and the comb and wattles were cyanotic. The next day marked dyspnea appeared which increased in intensity until the chicken died two days later. Postmortem examination revealed slight catarrhal inflammation, accompanied by pin-point erosions in the mucosa and sub-

mucosa of the intestines. The anterior trachea manifested considerable grayish-white mucus in the midst of which were localized caseated areas. The middle portion of the trachea was slightly hemorrhagic. The bronchi, lungs, larynx, and other internal organs showed no lesions. The case was diagnosed as chronic infectious trachitis, culminating in relapse and death. This was the only instance in which a bird contracted infectious trachitis as a result of subcutaneous inoculation of virus. Cross infection was excluded by adequate controls which were kept under the same conditions and remained healthy throughout the experiment.

The second California virus was demonstrated in the tissues of the spleens, livers, and kidneys of chickens dead of infectious trachitis. The virus as measured by dilution and inoculation into healthy chicks by tracheal swabs, was no greater in the tissues of these organs than in the tracheal exudate.

Tissues of the liver, spleen, kidneys, and trachea may be used along with tracheal exudate to provide a larger quantity of virus of fair potency.

Continuous Passage of the First New Jersey Virus

Further studies of infectious trachitis viruses were made with two strains received from New Jersey. These were known as the first and second New Jersey viruses. Results with the first New Jersey virus are shown in Table 21.

TABLE 21.—TRANSFERS OF FIRST NEW JERSEY VIRUS.

	Transfer				Termination	
Number	Date	From	To	Method	Date	Result
First	7/1/30		V 2236	Intratracheal	7/4/30	Dead
			V 2237	Intratracheal	7/5/30	Dead
Second	7/5/30	V 2237	V 2239	Intratracheal	8/4/30	Dead
	7/7/30	V 2236	V 2238	Intratracheal	7/10/30	Dead
Third	7/11/30	V 2238	V 2244	Intratracheal	7/15/30	Dead
			V 2245	Intratracheal	7/16/30	Dead
Fourth	7/15/30	V 2244	V 2250	Intratracheal	7/22/30	Dead
			V 2251	Intratracheal	....	Unaffected

Chicken V 2236.—At necropsy the general condition of the carcass was good. The face was pale, and the feathers were ruffled. One small patch of pseudomembrane was found in the pharynx immediately above the larynx. Desquamative epithelial inflammation of the trachea was evident. The desquamated areas were hemorrhagic. The blood in the heart and large arteries was unclotted, although the bird had been in the ice box several hours previous to necropsy. The liver showed a few areas of fatty degeneration. The kidneys were hemorrhagic. The spleen was congested. Except for the unclotted blood, this case was typical of infectious trachitis as observed hitherto.

Chicken V 2237.—The general condition was good: the lungs were tough,

dark pinkish-white in color, and of a parboiled consistency; the bronchi were congested and hemorrhagic up to the syrinx; the trachea, larynx, and pharynx were normal; there was fatty degeneration of the liver and hemorrhagic inflammation of the kidneys, with deposition of urates in the abdominal cavity. This was the first case observed in these experiments in which the bronchi were affected. The light in the brooder was accidentally turned off and the bird developed broncho-pneumonia, in addition to infectious trachitis. Apparently bronchitis is a symptom of broncho-pneumonia.

Chicken V 2239.—At necropsy a thick, cheesy pseudomembrane was found occluding the larynx. The anterior half of the trachea was mucopurulent, while the posterior part was normal. The liver and kidneys were slightly swollen and congested. This case was more typical of infectious trachitis than the former.

Chicken V 2238.—The carcass showed no marked indications of loss of flesh. The trachea and larynx were hemorrhagic. The blood in the heart and large arteries was unclotted and dark in color. Also the sides of the cage were stained with small specks of blood which had been expelled by coughing and sneezing. Fatty degeneration of the liver was present. The kidneys were hemorrhagic, especially in the tubular areas. The cut surface of the tubules appeared swollen and dark red in color, while the interstitial portion was almost white. The parenchyma and interstitial tissues were clearly differentiated in the kidneys. The spleen was congested and of a darker hue than normal for chickens.

Chicken V 2244.—The gross pathology was typical of the New Jersey strain of infectious trachitis. This virus appeared to produce more hemorrhagic symptoms than either the Massachusetts or California strains.

Chicken V 2245.—The gross pathology was similar to the findings in the case of V 2244, except that there was an abundance of pseudomembrane in the larynx and trachea. Prominent lesions noted in other parts of the body were unclotted blood in the heart and large arteries, petechiae on the pericardium, congestion of the liver, hemorrhages in the tubules of the kidneys, and blanching of the interstitial layers of the same.

Chicken V 2250.—The general condition was good. A few patches of pseudomembrane were found in the larynx and trachea. Coagulation necrosis and fibrinous inflammation were evident in the mucosa of the trachea. Some of the blood in the heart, large arteries, and veins was unclotted, although the chicken had been in the ice box for twenty-four hours before postmortem examination. The kidneys were hemorrhagic and the blood remained unclotted in the tubular spaces.

Chicken V 2251 did not react to the treatment.

In these experiments the first New Jersey strain of infectious trachitis was carried through five transfers covering a period of 22 days. During this time the virus showed no signs of deterioration. Excluding V 2251, which resisted infection, the average period of incubation was three days, while the average length of course was eight days. The shortest period of course was three days in two cases, and the longest period was thirty days in one case.

Continuous Passage of the Second New Jersey Virus

The second New Jersey virus was transmitted in series at the same time as the first virus. The results are given in Table 22.

TABLE 22.—TRANSFERS OF SECOND NEW JERSEY VIRUS.

Transfers				Termination	
Number	Date	Chicken	Method	Date	Result
First	7/1/30	V 2240	Intratracheal	7/5/30	Dead
Second	7/15/30	V 2241	Intratracheal	7/11/30	Dead
Third	7/11/30	V 2248	Intratracheal	7/16/30	Dead
Fourth	7/16/30	V 2249	Intratracheal	7/21/30	Dead
Fifth	7/21/30	V 2254	Intratracheal	7/28/30	Dead
Sixth	7/28/30	V 2255	Intratracheal	8/2/30	Dead
Seventh	8/2/30	V 2280	Intratracheal	8/9/30	Dead

The second New Jersey virus, like the second California virus, was carried through seven chickens from one to three months of age, for a period of one month and nine days without losing in virulence. The hemorrhagic sequala associated with the lesions of the first New Jersey virus were noticed in the chickens dead of the second virus.

The Filtrability of the First New Jersey Virus

The trachea was removed from chicken V 2238 as aseptically as possible, ground up with sterile saline solution in a mortar, and placed in the ice box over night. The next day, July 12, 1930, the solution was run through a Berkefeld V filter, after the coarser particles had been removed by filtration through sterile gauze; and two chickens, V 2246 and V 2247, were inoculated intratracheally with the filtrate. No reaction occurred in seven days. On July 19 these chickens were inoculated with unfiltered exudate from the trachea of V 2245. No reactions occurred. It was concluded that these chickens were immune.

Chickens V 2242 and V 2243 were inoculated intratracheally with Berkefeld N filtrate from the trachea of chicken V 2237. No reactions took place for eleven days. On July 19, these chickens were inoculated with virus from V 2245. Chicken V 2242 died of infectious trachitis in five days and V 2243 died of the same disease in nine days. The symptoms and pathology were typical of the disease under investigation.

On July 16 chickens V 2252 and V 2253 were inoculated intratracheally with virus from V 2244 and V 2245 after it had passed through a Seitz filter. Seven days later both chickens died of infectious trachitis.

These experiments demonstrated that the virus of the first New Jersey strain of infectious trachitis was filtrable, as it readily passed the Seitz filter, but it did not pass the Berkefeld N filters in sufficient quantities to cause infectious trachitis in chickens inoculated intratracheally with the filtrate.

Intravenous Inoculation with the First and Second New Jersey Viruses

On July 25, 1930, Rhode Island chickens MA 31000, MA 94488, MA 94492, and MA 94494 received intravenously 1 cc. of Seitz filtrate from chickens V 2240 and V 2280, which had died of infectious trachitis following intratracheal inoculations with the second New Jersey virus. These chickens did not contract infectious trachitis as a result of the intravenous injections, but were living and in good health three months after the treatment. The control chickens, MA 94485 and MA 94487, inoculated intratracheally with the same filtrate, at the same time, died of acute infectious trachitis four and five days, respectively, after inoculation.

MA 94498 and MA 94499 were injected intravenously with 1 cc. of Berkefeld filtrate of the first New Jersey virus of infectious trachitis from chicken V 2245. These chickens remained healthy and well for three months without showing any indications of disease. However, the controls, MA 94493 and MA 94497, inoculated intratracheally with the same filtrate, died of acute infectious trachitis in five and seven days, respectively.

Apparently virus of sufficient strength to kill birds inoculated intratracheally, has no effect when injected intravenously.

The Viability of Infectious Trachitis Virus

From the beginning of these experiments it was evident that the virus of the tracheal exudates could not be depended upon to maintain its virulence, for susceptible birds, for more than twenty-four hours at room temperature, or three days in the ice box. However, viruses preserved by the Swift (1921) method maintained their potency much longer. The longest period of viability for the first California virus was two months and twenty-six days, while the shortest was two weeks. The average was four weeks and two days as indicated in Table 23. One of the first New Jersey strains, which was especially virulent, maintained its potency for three months when preserved by the Swift method. The average was four weeks and five days (Table 23).

TABLE 23.—VIABILITY OF INFECTIOUS TRACHITIS VIRUS UNDER DIFFERENT CONDITIONS.

Virus	Transfer	Viability		
		Room temperature	Ice box	Swift method
		Hours	*Days*	*Days*
Granby	First	24	7	.
	Second	20	4	
	Third	20	2	
	Fourth	24	3	.
Amherst	First	24	5	.
California I	Eighth	18	3	30*
New Jersey I	Sixth	10	3	35*

* Average.

These experiments indicate that the virus of infectious trachitis does not live more than a day or two outside of live birds when exposed to light, air, and decomposition. However, in the winter under freezing conditions, such viruses may last for five days or a week, and under especially favorable conditions of freezing and drying they may even last longer.

Carriers

Table 24 contains some data on acute and chronic carriers, which show that the virus was present in the tracheal exudate in all but a comparatively few of the acute cases of the disease. It was also found in the cloacal contents of three of the birds inoculated with the first California virus and four of the cockerels and pullets treated with the first New Jersey virus. The virus of infectious trachitis was not demonstrated in the intestinal contents or in the blood of any of the birds studied in these experiments.

Two chronic carriers were found harboring the virus in the tracheal

TABLE 24.—A TABULATION OF THE EXPERIMENTS ON CARRIERS.

Substance examined	Name of virus	Course of the disease	Number of birds		
			Total examined	Virus present	Virus absent
Tracheal exudate	Granby	Acute	13	9	4
		Chronic	1	0	4
	Hadley	Chronic	5	0	5
	Leverett	Chronic	7	4	3
	Westwood	Chronic	15	0	15
	So. Lincoln	Chronic	8	0	8
	Gardner	Chronic	10	1	9
	Watertown	Chronic	3	0	3
	California I.	Acute	30	27	3
		Chronic	5	1	4
	New Jersey I.	Acute	15	13	2
		Chronic	2	0	2
Intestinal contents	California I.	Acute	5	0	5
	New Jersey I.	Acute	5	0	5
Cloacal contents	California I.	Acute	5	3	2
		Chronic	5	0	5
	New Jersey I.	Acute	5	4	1
		Chronic	2	0	2
			144	62	82

exudate of sufficient virulence to cause death in susceptible cockerels These chronic carriers had previously suffered an attack of infectious trachitis due to intratracheal inoculation of the Gardner and California strains of the disease, and had recovered from the acute stage in two and four weeks, respectively. They represent 3 per cent of the total number of chronic cases examined. If, after every outbreak of infectious trachitis, 3 per cent of the birds are carriers for an indefinite period after the acute stage has subsided, it is evident that such flocks are a potential danger to susceptible birds as long as the carrier stage exists.

From a total of 144 birds examined, showing visible symptoms of infectious trachitis, the virus was found in either the secretions or excretions of 62, or 75.61 per cent. Two of these birds developed into healthy carriers, in which the virus in the tracheal exudate remained viable for two and four weeks after all visible symptoms of the disease had disappeared.

Does Chickenpox Vaccination Protect Against Infectious Trachitis?

Some of the birds mentioned in preceding experiments were reported to have been vaccinated against chickenpox. As far as could be determined with these birds, chickenpox vaccination did not increase the resistance of the birds against infectious trachitis or influence the course of the disease. Since the chickenpox vaccinations were done outside of the laboratory, and nothing was known about the thoroughness of the work or the effect of the vaccine upon the birds, the results were unsatisfactory.

In order to get more reliable data on the effect of chickenpox vaccination against infectious trachitis, nine fowls, four pullets, four cockerels, and four chickens were secured from unvaccinated flocks. These birds were vaccinated with a vaccine which had been tested previously and found effective against chickenpox. Every one of the 21 birds showed lesions of chickenpox within 14 days and failed to react to a second chickenpox vaccination with a different strain of vaccine.

The nine fowls were treated with Granby virus which possessed marked virulence, and two were killed.

The cockerels, pullets, and two of the chickens, V 2397 and V 2410, were inoculated with California virus. One cockerel, two pullets, and both of the chickens died as a result of the inoculations.

Chickens V 2398 and V 2399, after recovering from chickenpox, were tested with the first New Jersey virus and both died.

All the other birds had severe attacks of infectious trachitis, but recovered after the disease had run a natural course.

There was nothing in these experiments to indicate that chickenpox vaccination protected fowls, cockerels, pullets or chickens from infectious trachitis; as a matter of fact, it tended to predispose to infectious trachitis by lowering the vitality of the birds. Apparently chickenpox and infectious trachitis are two different diseases symptomatically, pathologically and immunologically. Possibly they are different bacteriologically, since the virus of infectious trachitis did not pass the pores of the Berkefeld N filter as readily as the chickenpox virus.

Summary

1. The name infectious trachitis is suggested for the disease sometimes called infectious bronchitis, tracheolaryngitis, chicken flu, and Canada flu, because it is short, easily pronounced, and descriptive of the symptoms and chief lesions.

2. The prevalence of infectious trachitis in Massachusetts previous to 1920 and 1921 is uncertain. However, it is known that the disease has progressively existed in the State since 1921.

3. The clinical symptoms of infectious trachitis, as noted in this study, were pale face, ruffled appearance of the feathers, lacrimation of the eyes, elevation of temperature, lack of appetite sometimes accompanied by emesis, cyanotic coloration of the comb and wattles, dyspnea, weakness, the formation of pseudomembrane in the visible parts of the respiratory tract, swelling of the infraorbital sinuses, death due to suffocation, toxemia, or general debility.

4. Gross lesions of infectious trachitis were especially prominent in fowls and absent in young chickens dead of the disease. The most common lesions of infectious trachitis revealed by this investigation were desquamative epithelial inflammation of the trachea, the formation of pseudomembrane in the respiratory tract, congestion and sometimes fatty degeneration of the liver, inflammation of the spleen and hemorrhages of the kidney. Congestion and consolidation of the lungs occurred in a few cases.

5. The histopathology of infectious trachitis varied considerably in individual birds. The following lesions were usually found in this study: hyperemia of the trachea, larynx and abdominal organs, desquamative inflammation of the ciliated epithelial layers of the trachea and larynx: fibrino-purulent infiltration of the mucosa of the trachea; hemorrhagic infiltration into the alveolar spaces of the lungs, tubular spaces of the kidneys, and the mucosa and submucosa of the trachea; inflammation and sometimes fatty degeneration of the liver. Inflammation of the spleen was observed in some cases.

6. Viruses from acute field cases of infectious trachitis were successfully propagated under laboratory conditions. Viruses from chronic field cases of infectious trachitis lost their potency when transmitted in series under laboratory conditions.

7. Viruses from the acute field cases of infectious trachitis studied in this investigation were filtrable. These viruses consistently passed the pores of Berkefeld V and Seitz filters in sufficient quantities to successfully inoculate fowls, pullets, cockerels, and chickens. Some of the viruses were partially retained by the Berkefeld N filters, used in these experiments, so that susceptible birds were not always successfully inoculated with the filtrates. These viruses were not demonstrated in the filtrates passing through Berkefeld W filters.

8. Fowls, pullets, cockerels, and chickens were not successfully inoculated by the subcutaneous method.

9. Six chickens inoculated intravenously with the virus of infectious trachitis failed to develop the disease, while the controls inoculated intratracheally with the same virus died.

10. Comparative studies of infectious trachitis from Massachusetts, California, and New Jersey showed immunological differences between acute and chronic cases.

11. The virus of the second California strain of infectious trachitis was demonstrated in the macerated tissues of the liver, spleen, trachea and kidney of chickens dead of the disease.

12. Two healthy carriers of infectious trachitis were found, in which the virus remained viable in the tracheal exudate for two and four weeks, respectively, after all visible symptoms of the disease had disappeared.

13. The virus of infectious trachitis was demonstrated in the cloacal contents of three of the birds infected with the first California virus and four of the cockerels and pullets suffering from an infection with the first New Jersey strain.

14. Chickenpox vaccination did not protect domestic fowls against infectious trachitis.

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Acknowledgments

In conclusion the author wishes to extend his sincere thanks to Professor William H. Davis, Botany Department, Massachusetts State College, for cooperation in taking the microphotographs showing the lesions of infectious trachitis, and to Doctor J. R. Beach, University of California, and the Rockefeller Institute for Animal Diseases, for contributing the California and New Jersey strains of infectious trachitis.

Doctors Henry Van Roekel, G. L. Dunlap, and Professor William C. Monahan contributed viruses at critical times during the course of this study. This assistance was appreciated.

Publication of this document approved by Commission on Administration and Finance
3m-4'31. No. 1983.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 274 April, 1931

The Identification of Apple Varieties From Non-Bearing Trees

By J. K. Shaw and A. P. French

Much of the disappointment and financial loss caused by planting misnamed trees could be avoided if varieties were known as young trees in the nursery, or even if misnamed trees were detected soon after planting in the orchard. Varieties of apples can be recognized by tree and leaf characters as easily and surely as by the characters of the fruit. This bulletin discusses and illustrates some of these characters.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE IDENTIFICATION OF APPLE VARIETIES FROM NON-BEARING TREES

By J. K. Shaw, Research Professor, and A. P. French, Assistant Professor of Pomology

Introduction

In a former bulletin by the senior author (18) leaf characters of apple varieties were discussed, and a future publication dealing with tree characters was promised. This paper is presented in fulfillment of that promise and, inasmuch as Bulletin 208 is out of print and is still frequently asked for, includes also some of the information given in the earlier publication.

No one can learn to know varieties from the printed page even when supplemented with an abundance of good illustrations; the trees must be studied as they stand in the nursery or orchard. One may first study a single variety, the identity of which is surely known, until its distinguishing characters are learned, then observe how a second variety differs from the first and what distinguishes it from other varieties, and so on with a third and additional varieties. Practically all apple varieties can be distinguished one from another by leaf and tree characters by the well-trained observer. An exception obtains in the case of red-fruited bud sports, several of which are now being propagated in nurseries. The writers have compared a number of these with the varieties from which they sprung, and the only possible distinguishing character observed is a slightly darker color of foliage and bark. It is doubtful if this is marked enough to definitely separate the sport from its parent in a mixture. It has not been possible to find means of distinguishing between Ben Davis, Gano, and Black Ben, which may give support to the suggestion that these two varieties may be bud sports of Ben Davis.

While it lies outside the scope of this paper, it may be said that pear and plum varieties may be identified nearly or quite as readily as apples; cherry varieties may be somewhat more difficult than apples; but some peach varieties which are quite different in fruit resemble each other in tree characters so closely as to make it difficult if not impossible to tell one from another before they come into bearing. Yet most varieties can be distinguished beyond reasonable doubt, and most mixtures in nursery rows can be detected and the misnamed trees eliminated from the row.

Review of Literature

While this bulletin discusses only apple varieties, a review of the more important publications dealing with varietal characters of non-bearing trees of various cultivated fruits seems worth while. These vegetative characters have received far less attention than fruit characters. Some of the early pomologists included brief notes on plant characters along with

their fuller descriptions of the fruits; but not until quite recently has any serious attempt been made to distinguish varieties in the absence of the fruit itself.

As early as 1877 Beal (2 and 3) described the flower characters of some 88 varieties of apples and found the petals and styles of prime importance. The same author (4) later made a study of the distinguishing characters of pear flowers but found them less distinct and less easily classified than apples. More recently Bunyard (6) used the characters of the flowers as a means of identifying apple varieties; while Blake (5) made a similar study with peach flowers, using such characters as diameter of flower, width of petal, length of pedicel, length and width of sepals, form of calyx tube, and color of calyx cup.

Several authors have mentioned differences in the seedling root system of nursery apple trees. Swarbrick and Roberts (21) present cuts of typical root systems of several varieties to substantiate their statement that "root character is as typical of a variety as is the top growth," while Roberts (14) says that the anatomical structure as well as the type of development of the root is affected by the scion variety. Shaw (17) reports that the main roots differ in number, size, length, place of origin and angle formed with the main axis; also that there is a relation between the form of top and that of the root system.

While the differences in the root system may be of importance after the tree is dug, the more valuable characters for identification are in the top of the nursery tree. Thomas (24) was one of the first to give serious consideration to differences in shoot, bud, and leaf characters. He specifically mentions the "serratures" of the leaf as being "characteristics of importance". Shaw (15 and 16) expands on this plan, describing the tree and leaf characters of a number of common apple varieties. The same author's later publication (18) is devoted entirely to leaf studies, using such characters as size, shape, and folding of the blade, surface texture, pubescence, thickness, and serratures.

On the peach Gregory (10) finds the type of gland to be of value; but in the case of plums, Dorsey and Weiss (8) consider them of little value, being mostly globose in type and extremely variable in number and position in different leaves of the same variety. Alderman and Shoemaker (1) have studied the leaf characters of plum varieties in Minnesota and find that serratures and size and shape of blade are most valuable characters. Upshall (26 and 27), in his study of nursery trees other than apple, attempts a classification of plums, based upon pubescence of shoot, color of tip leaves, and position of glands; one of peaches using gland type, amount of yellow pigment in the leaves, crinkling of leaves, and time of leaf fall. He groups pears according to shoot color, and sweet cherries according to the presence or absence of pubescence on the petiole of young leaves. His findings have been augmented by Shoemaker's (19 and 20) studies of additional varieties and characters of these same four fruits.

French (9) has measured the differences in vigor of growth of apple varieties which are evident even in one-year trees, while a detailed study of the dormant characters of fruit trees has been made by Bunyard (7). He considers the various characters of shoot growth and buds, and form of the mature tree, placing particular stress upon the differences in hardness of wood in the apple; form of wood bud in the pear, plum and cherry;

pubescence of shoot and prominence of bud support in the plum.

Not all the work of this nature has been confined to tree fruits. Grubb (11) has studied the characteristics of the new canes and fruiting canes of raspberry varieties in England; while Winter (28 and 29) presents a key to the varieties grown in Minnesota based upon presence and position of glands, form of leaflets, and form, quantity, and color of bristles. In the case of currants, Thayer (22) has formulated a key using foliage characters, while in his later publication (23) flower, fruit, and foliage characters are used to separate varieties of red and white currants into several fairly distinct groups. Maynard (12) has attempted a classification of strawberry varieties using position of hairs on the petiole, color of stipules, color of foliage, surface of leaflet, curvature of the lamina and leaflet, and other plant, flower, and fruit characters.

Tree Characters

The varietal characters of growth, bark, bud, and wood are of great value in recognizing varieties from the non-bearing trees. One depends on them in about the same degree as on the leaves. When the trees are dormant they are, of course, the only characters available. While they are then more distinct than in actively growing trees, yet identification is less positive with dormant trees than with those having leaves.

Size and Vigor

The size of an individual tree depends mostly on age and on soil and other environmental conditions; yet there are size differences that are of great value in recognizing varieties. Williams is likely to be smaller than most other varieties. Arkansas and Fall Pippin under most conditions make large trees. Often a stray tree or group of trees in the nursery row is betrayed by a size difference. In the rather common mixture of Stayman and Winesap, the larger Stayman trees often show up in a striking manner. Too much stress should not be placed on size of tree, however, for trees all of one variety often contain individuals varying in size so as to suggest a mixture.

Form or Shape of Top

Trees that are two years old or older show differences in the form of the top that are characteristic of the variety. Form depends largely on the angle formed by the main branches and the trunk or axis of the tree and on the amount of curvature of these main branches. If the branches show little or no curvature, the top is said to be *diverging*. Depending on the branch angle, the form may be said to be *narrowly diverging* as in Sutton, *moderately diverging* as in Northern Spy, or *broadly diverging* as in Stayman. In a similar way those varieties having distinctly curved main branches are said to be *narrowly upcurving* (Wagener), *moderately upcurving* (Red Astrachan), or *broadly upcurving* (Gravenstein).

Some varieties show these forms very distinctly, but many do not fall clearly in any one class and are said to be more or less *irregular*, as Baldwin and McIntosh. Most varieties are intermediate and require qualifying terms to convey with any accuracy an idea of the form of the top.

As one looks down the rows of two-year trees of different varieties in the nursery, the form of the top shows up very distinctly. The narrowly upcurving trees of Wagener make narrow rows with a wide space between, while the broad-topped varieties have little space between the rows. A group of trees growing from the buds of a single bud stick is often betrayed to the observer by their different form of top.

Bark Color

The color of the bark in young trees is of great importance in identifying varieties. The tips of growing shoots are always some shade of green and all varieties are much alike. With the maturing of this wood later in the season characteristic colors appear. This color may change the next year; therefore one should pay attention to the bark color of the one-year shoots below the growing tips and also of the older bark. Bark color is generally some blend of *green*, *yellow*, and *red*. Innumerable shades and blends of these three colors appear, and in few cases are two varieties exactly alike in bark color. It is impossible to convey in words a picture of the color of any variety. It can be expressed only roughly, but one should always note bark color and compare different varieties very carefully.

Some varieties have irregularly distributed over the surface shreds and patches of a silvery grayish bark called the *Scarf-Skin*. This is often seen on Stayman and is helpful in distinguishing it from other varieties of the Winesap group. Stark shows distinctly a considerable amount of Scarf-Skin.

Bark color in dormant trees is always darker than in growing trees. It is more constant and becomes of great value in identifying varieties in the dormant condition.

Shoot Characters

There are certain peculiarities of the shoots or twigs (growths of the current growing season) that are of help in recognizing varieties. Mention has been made of the varying degrees of curvature that determine in part the form of the top. Some varieties, as Stayman and Rhode Island Greening, have *stout* shoots while those of Yellow Transparent and Jonathan are *slender*. In some varieties many of the buds start into shoot growth giving a *dense* top. Examples are Yellow Transparent and Grimes. Others make a more open top. In Northern Spy and Rome many buds fail to grow at all, leaving bare spaces on the two-year wood. However, in these two varieties most of the buds that do start grow into shoots instead of spurs, giving a rather dense top. In Tompkins King most of the buds grow into short spurs while only a few develop into long stout shoots. These characteristics of shoot growth are more evident in young orchard trees than in nursery trees.

There are other shoot characters that are useful. Some varieties make a zigzag growth, while others are straight. In the former the direction of the successive internodes (space between the buds or "eyes") is not in a straight line, while in the latter the shoots are straight from node to node though they may be more or less curved.

Leaf Buds

In the angle of every leaf is a bud which may develop into a branch shoot or fail to grow much, but develop a rosette of leaves. Often it fails to start and eventually falls off. The appearance of the buds is often characteristic of varieties, and in seeking for means of recognizing varieties the buds should not be overlooked. Buds of Wagener are distinct from all other common varieties, being large, broad, and quite woolly, and closely appressed to the shoot. Buds of other varieties are of varying shapes, more or less pointed and lying more or less close to the shoot. The slight elevation of the bark on which the bud grows often has characteristics peculiar to the variety.

Wood Hardness

There are considerable varietal differences in the hardness of wood. In general those varieties that are hardy to winter cold have harder wood than the tender varieties. Oldenburg and Yellow Transparent are examples of the former class, while Tompkins King and Stayman have softer wood. Wood hardness is best determined by cutting with a knife or shears but this is often impractical so this character is of minor value in ordinary identification work.

Lenticels or Dots

Scattered over the surface of the bark of both shoots and older wood are small corky dots known to botanists as lenticels. They are the breathing pores of the shoot. They vary in number, size, shape and color in different varieties. Within the variety there is some variation, but they are of great value in identification. Because they are often relatively inconspicuous they may escape the notice of many nurserymen. Winesap has few dots while McIntosh has many. Northern Spy has many dots and one may identify the variety by this peculiarity. In Stayman they are brownish in color, while in Arkansas (Mammoth Black Twig) they are whitish. Most dots are roundish in shape, but among those on Wealthy one will find a few that are elongated. This applies only to the dots on one-year-old shoots. On older wood the enlarging diameter of the shoots stretches the dots so that they become much broader and the elongated ones no longer appear.

In some varieties such as Winesap and Opalescent the dots are even with the surface of the bark, while in McIntosh and Wealthy they project slightly so that they may be felt on rubbing the thumb or finger over the surface of the shoot. This seeems a very minor character on which to base the identification of varieties but it is of distinct value in some cases.

Leaf Characters

In order to talk understandingly about the leaves, the different parts must have names. These are shown in Fig. 1, which is largely self-explanatory. The leaf is first divided into three parts: stipules, petiole and blade. About one-third of the blade next to the petiole is called the base, and similarly about one-third of the other end, the apex: beyond this is the narrow point

called the tip. The midrib is a continuation of the petiole to the tip of the leaf. The saw-like notches along the edge of the leaf are called serratures or serrations and are of the greatest importance, being rarely exactly alike in two varieties.

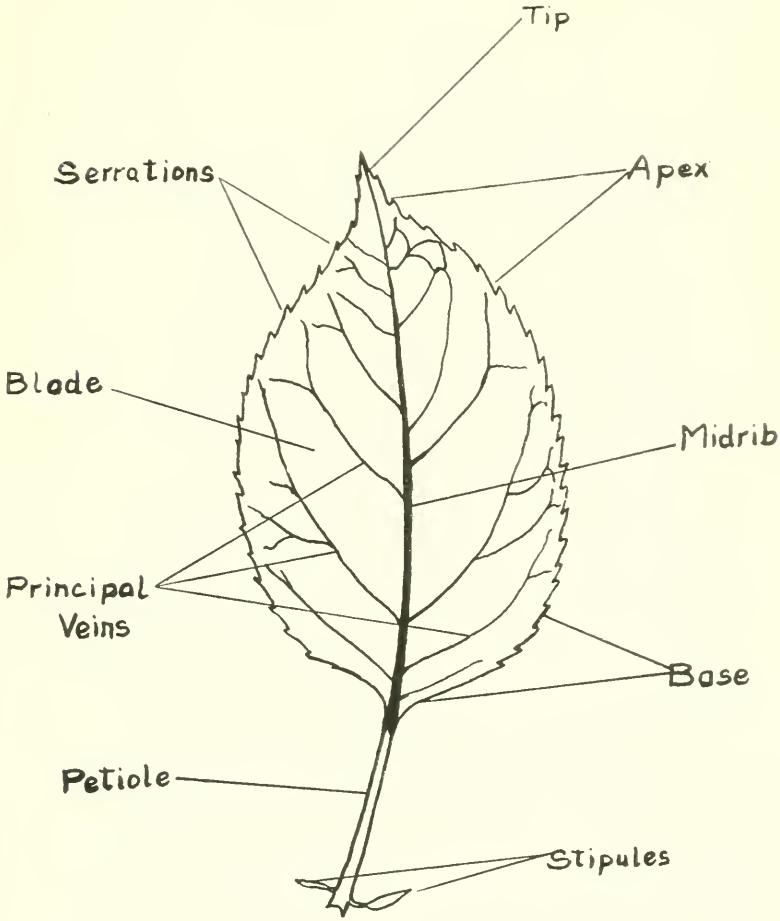

Fig. 1.—Diagram of Apple Leaf, Showing Parts.

Which are the Characteristic Leaves

The leaves on any tree can be divided into two groups: (1) the "single" leaves coming out on the current season's growth, and (2) the "rosette" leaves coming out of buds formed the previous season, i. e., on wood of last year's growth. *The latter should be discarded, and study and attention centered on the single leaves on the current season's growth.* Leaves that have been injured in any way, as by lice or other insects or by many scab spots or other diseases, are of little value for identification purposes. Leaves on weak shoots or in the interior of the tree should be avoided. *Study the well-developed uninjured leaves usually found along the middle of the season's growth.* Leaves on trees that are poorly nourished are often undersized and yellowish. Such leaves are not typical and should be observed with caution.

Inasmuch as leaves of the current season's growth are necessary, little progress can be made in leaf study until considerable growth has been made. Leaves on trees or shoots making excessive growth are apt to be distorted and are not typical. The most favorable period for observing the leaves is from July 1 until October 1. To one familiar with leaf characters this period may be extended somewhat.

To the beginner in leaf study the leaves of all varieties will look alike. Close and repeated observation will reveal differences that are peculiar to different varieties. The purpose here is to discuss the various parts of the leaf and how they differ in different varieties.

The Petiole

The petiole or stem of the leaf is sometimes characteristic of the variety, though it is of minor importance. Wealthy has a rather long, slender petiole, while that of McIntosh is usually short and stout. The angle which the petiole forms with the shoot on which it grows is often helpful in recognizing varieties. In the Northern Spy the angle is sharp, that is, the leaf is said to be upright; while in the Rhode Island Greening it is broad or spreading. This character is correlated with the form of the top. The Northern Spy has an upright head, while the Rhode Island Greening is distinctly spreading. This character of the head or form of the tree is quite well known to fruit growers and is further discussed elsewhere; but few are aware that in an unknown variety the form of the top can be foretold with considerable accuracy from the leaf angles on a one-year whip.

The Blade

Size.—The leaf blade furnishes the most dependable characters for variety identification. Consider first the size of the blade. This, of course, varies considerably with the vigor of the tree. Trees in a sod orchard making little growth will have much smaller leaves than will the same variety growing under cultivation and making a vigorous growth. Leaves well exposed to the sun will often be smaller than those growing in shade. With these reservations in mind, it may be said that the Jonathan (Fig. 29) has a small leaf, while Rhode Island Greening (Fig. 18) has large leaves; Wealthy (Fig. 21) is a little smaller than Baldwin (Fig. 4); and McIntosh (Fig. 2) a little larger than Wolf River (Fig. 3).

Outline.—The outline of the leaf may vary in different varieties in two ways: in relative length and width, and in the width of the base and apex. Winter Banana (Fig. 12) is relatively long and narrow, while Baldwin (Fig. 4) is relatively short and broad. An example of the second type is found in comparing Wolf River (Fig. 3), which is narrow at the base and apex, with McIntosh (Fig. 2), which is broad at the base and apex. This difference is especially valuable in distinguishing between Oldenburg (Fig. 20) and Wealthy (Fig. 21), the former being much broader at the base and apex than the latter.

Tip.—The narrow tip called the point is of some value, being larger and more slender in some varieties, usually those with a narrow apex, than in others.

Folding.—Various types of bending and folding appear in the leaf blade. The blade may be flat as in Gravenstein (Fig. 6) and Wealthy (Fig. 21), or it may be folded to a greater or less degree as in Baldwin (Fig. 4) or Grimes (Fig. 17). The latter two varieties exhibit different types of folding, being broad and saucer-shaped in the Baldwin, and much narrower and more pronounced in the Grimes. Leaves of a given variety may show this character in varying degree according to condition: the folding is more pronounced in periods of dry, sunny weather than it is during cloudy or rainy periods. Jonathan, as shown in Fig. 29, shows only moderate folding, but at times it may show very pronounced folding,—sometimes more than any variety illustrated here. Nevertheless, it is a most valuable character in the identification of varieties. The peculiar saucer-shaped folding of the Baldwin is always seen in greater or less degree in a considerable proportion of the single leaves on the tree, and with one or two other peculiarities will serve to distinguish this variety.

Next there is the bending or waving of the leaf edge. Flat leaves do not often show this, although it appears quite noticeably in Oldenburg and Wealthy, neither of which is folded very much. Some folded leaves are very distinctly waved, as Grimes (Fig. 17) and Yellow Transparent (Fig. 28); while others show it little or not at all, as Baldwin (Fig. 4) and Winter Banana (Fig. 12).

A third type of bending or folding of the leaf blade is seen in the bending backward or reflexion of the midrib. Pronounced reflexion of the midrib is not common in flat leaves, but is the usual thing in strongly folded leaves if the folding is of the narrow type. Thus Baldwin (Fig. 4.) and Gravenstein (Fig. 6) are not reflexed, while Grimes (Fig. 17) and Rome Beauty (Fig. 16) are strongly reflexed.

Serrations—Probably the most dependable leaf character for identifying varieties is the nature of the serrations along the edge of the leaf. They are sharp in Rhode Island Greening (Fig. 18) and dull in Wolf River (Fig. 3) and Wealthy (Fig. 21). Other varieties are intermediate between these extremes, but every variety is peculiar to itself and different from other varieties. In Rhode Island Greening the serrations are distinct or well separated, while in Gravenstein (Fig. 6) and Baldwin (Fig. 4) they are set close together or indistinct. They vary in depth also; and in some varieties they are straight, as in Rhode Island Greening, while in Baldwin they are often slightly curved or sickle-shaped. The last peculiarity, together with saucer-shaped folding referred to above, serves to distinguish Baldwin from all other common varieties known to the writer. If one leaf is laid upon another so that

the serrations of both can be seen and carefully compared, the observer with some experience can very often tell quite positively whether the leaves represent one variety or two varieties.

Texture—The veins of the leaf divide and subdivide until they form a network all over the surface of the leaf. This network is coarser in some varieties than in others. There are other peculiarities in the veining hard to describe in words, but evident and distinct in the leaves. These peculiarities taken together are spoken of as texture. The texture of Rhode Island Greening (Fig. 18) is very different from that of McIntosh (Fig. 2). Comparisons of other varieties will show differences in texture difficult to picture in words, but of much value in recognizing varieties.

Pubescence—All varieties have more or less growth of short hairs over the under surface. Those having an abundant growth of these hairs are said to be pubescent or "woolly." This is not shown very clearly in the figures, but may be seen by observing the leaves themselves. Ben Davis and Jonathan are examples of "woolly" leaves, while Rhode Island Greening shows very little of this growth. This hairy growth is sparse on Baldwin and more abundant on Hubbardston and McIntosh.

Surface—In some varieties, as Grimes (Fig. 17), the surface of the leaves is smooth and shining, while at the other extreme are some varieties such as Wealthy (Fig. 21) that appear rough and dull. The peculiarities in surface, like so many other characters, are hard to describe but are very distinct and significant to one familiar with varieties.

Thickness—Varieties differ also in the thickness of the leaves. McIntosh and Wealthy have relatively thick, stiff, rigid leaves, while those of Rhode Island Greening, Grimes, and Fall Pippin seem thinner and less rigid to the touch. Oldenburg leaves are thick and crisp, while those of Yellow Transparent are soft and flexible.

Color—All apple leaves are, of course, some shade of green in color. The color depends a good deal on the vigor of the trees, being deeper in vigorous trees, and a paler, more yellowish green in trees making little growth. There are distinct varietal differences in color. In Rhode Island Greening and in all green-fruited varieties the color is a rich, clear green. This is not true of yellow varieties such as Sweet Bough and Yellow Transparent, which have leaves of a yellowish-green cast. In varieties that have much red in the color of the fruit, as McIntosh, the leaves are a deeper green, sometimes with a slight bluish or purplish cast. These differences in leaf color are not pronounced, and as stated above vary with the condition of the trees, but they are very helpful in recognizing varieties. An abundance of pubescences gives a grayish cast to leaf color.

There are many other characteristics of both tree and leaves that are useful in identifying varieties, but those mentioned are the most important and most often relied upon. Others will be found by the careful observer in studying trees of different known varieties. When one has come to know thoroughly the peculiarities of a variety, he will be able to tell whether or not a tree, the variety name of which is unknown, is like another tree the name of which is known. When one has their variety characteristics committed to memory and carries a picture of any variety in his mind, he will be able to recognize that variety whenever and wherever it may be met with.

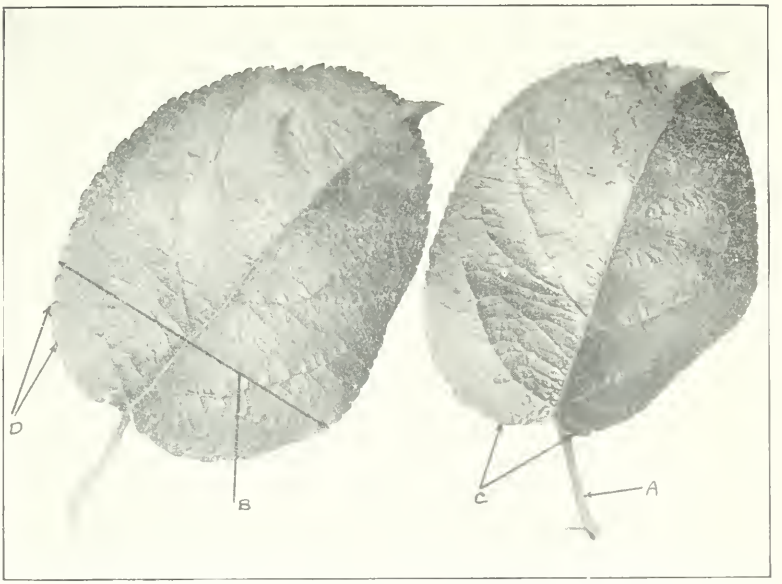

Fig. 2.—McINTOSH. Petiole short (A); blade large, flat or slightly folded near edge, broad (B), and heart-shaped at base (C), deep bluish green; serrations rather dull and shallow, especially at base (D). Tree large; shoot bark reddish; lenticels many, distinct. Leaf texture rather coarse.

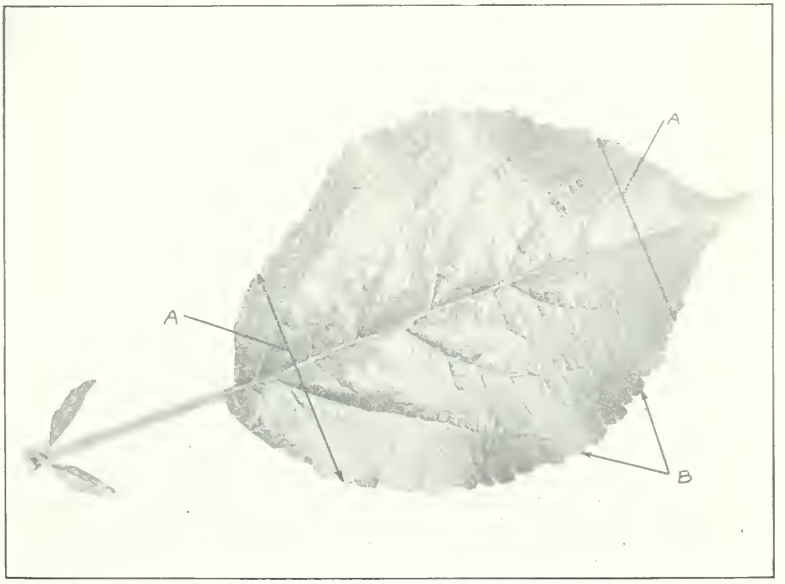

Fig. 3. WOLF RIVER. Petiole long; blade more or less folded, narrow at base and apex (A); serrations coarse and dull, often double (B); leaves usually more folded than shown here. Tree large; shoots upright, spreading, rather slender, reddish; leaves rather light green.

NOTE: These leaf photographs are reduced to approximately two-thirds of the size of typical leaves of the variety.

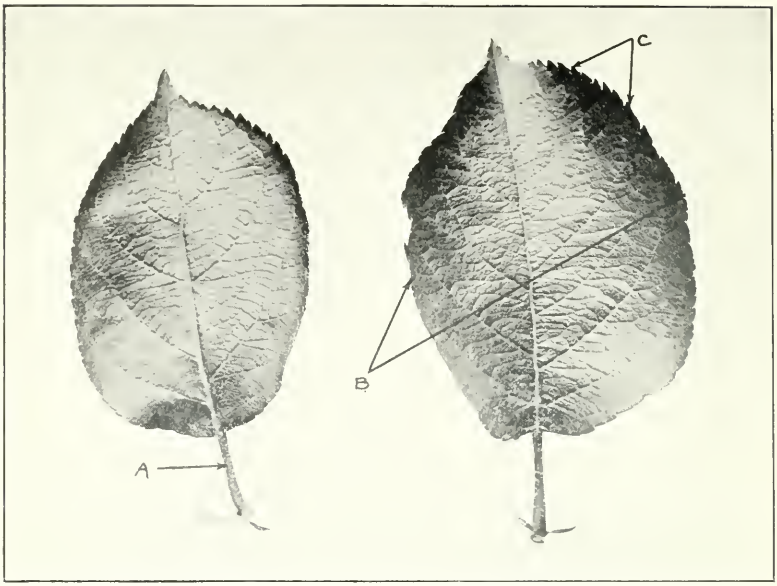

Fig. 4.—BALDWIN. Petiole short (A); blade large, broad with "saucer-shaped" folding (B); serrations sharp, close set, usually curved (C). Tree tall; shoots moderately stout, somewhat spreading; lenticels large, whitish.

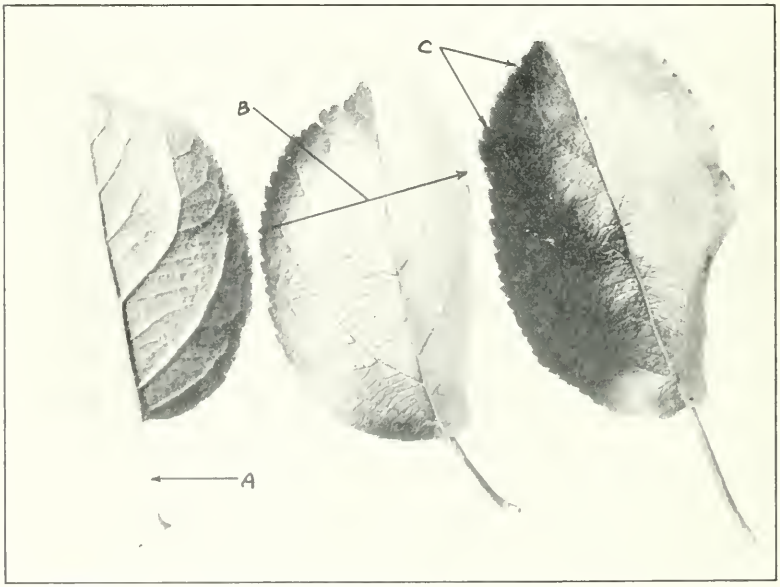

Fig. 5.—"FALSE BALDWIN." Petiole medium (A); blade somewhat folded and waved (B); serrations moderately distinct and little curved (C). Resembles Baldwin. See p. 83.

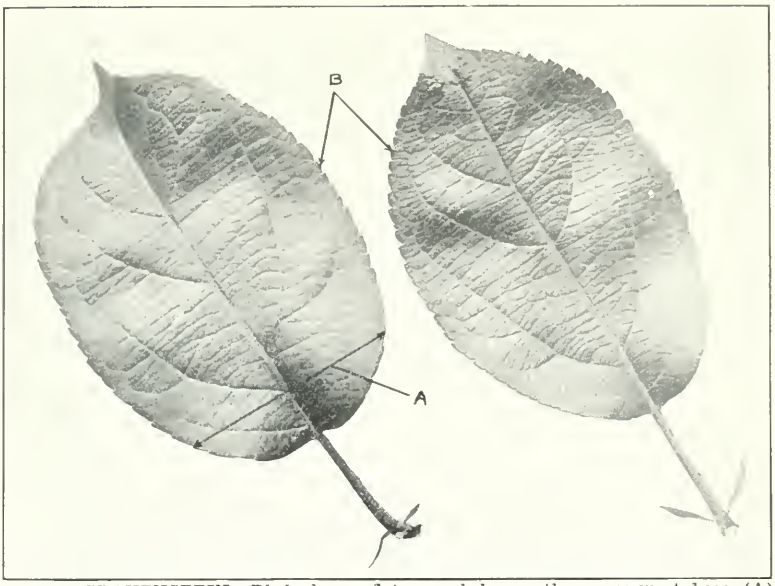

Fig. 6.—GRAVENSTEIN. Blade large, flat, rounded or rather narrow at base (A); serrations moderately sharp and shallow (B), fairly regular. Tree large; shoots stout, broadly upcurving; bark yellowish; lenticels few; leaves stiff and leathery.

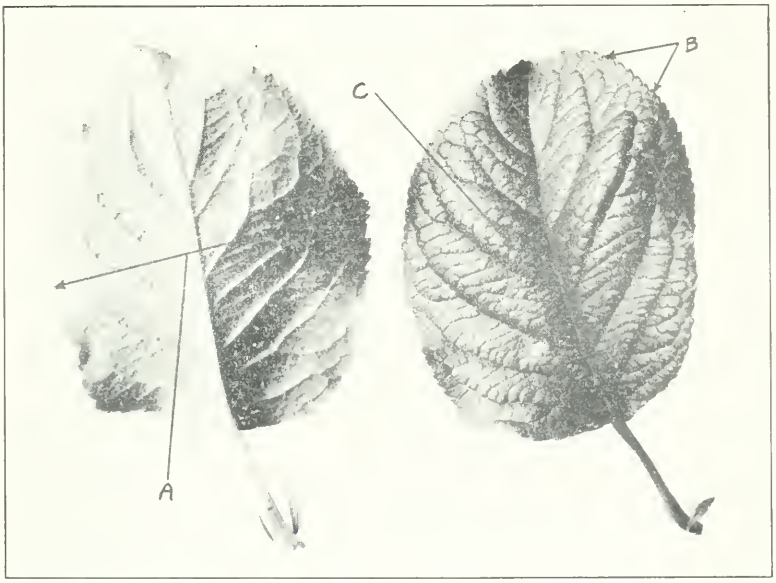

Fig. 7.—"FALSE GRAVENSTEIN." Leaf very broad (A); serrations rather distinct (B); texture coarse (C). Has been frequently mixed with Gravenstein. See p. 83

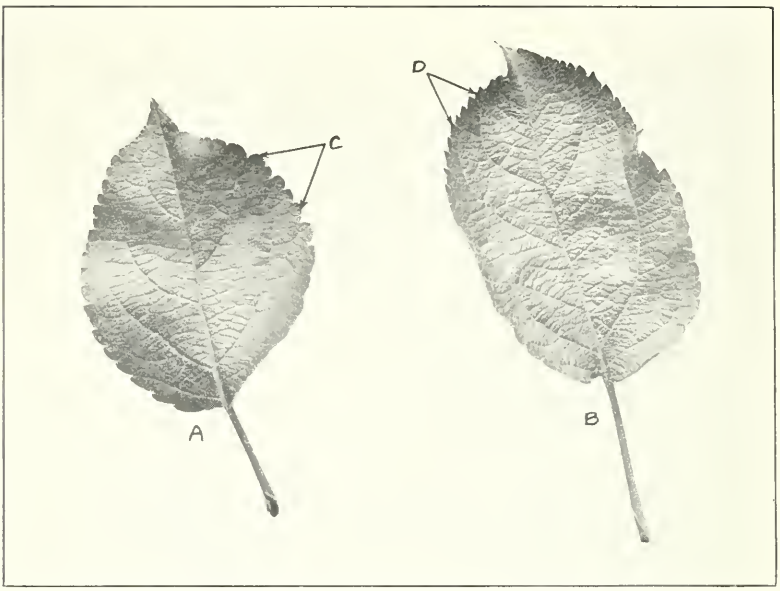

Fig. 8.—WINESAP. Blade medium or below in size, nearly round (A), or oblong (B); serrations sometimes dull and coarse (C), sometimes sharp (D). An exceptional variety, often having leaves of two distinct types. Tree rather small; shoots slender, dark reddish.

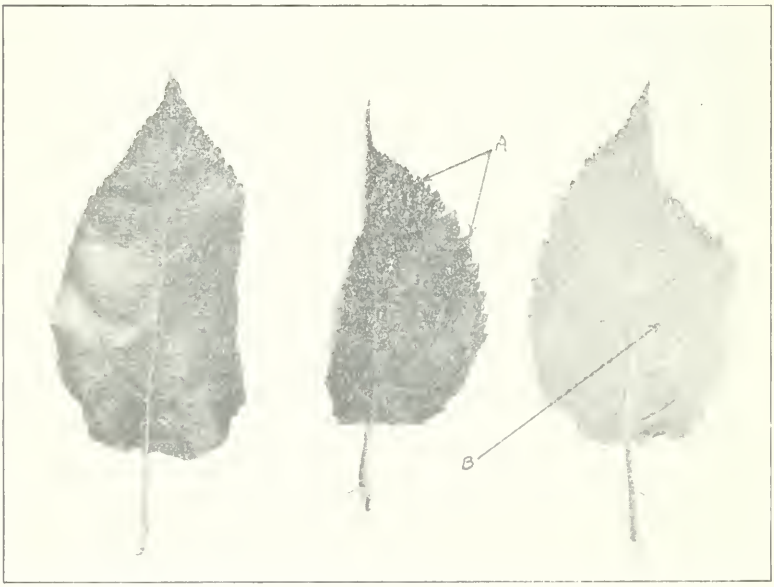

Fig. 9. STAYMAN. Serrations rather coarse and irregular (A); pubescence rather abundant and coarse (B). One of the Winesap group. See p. 85.

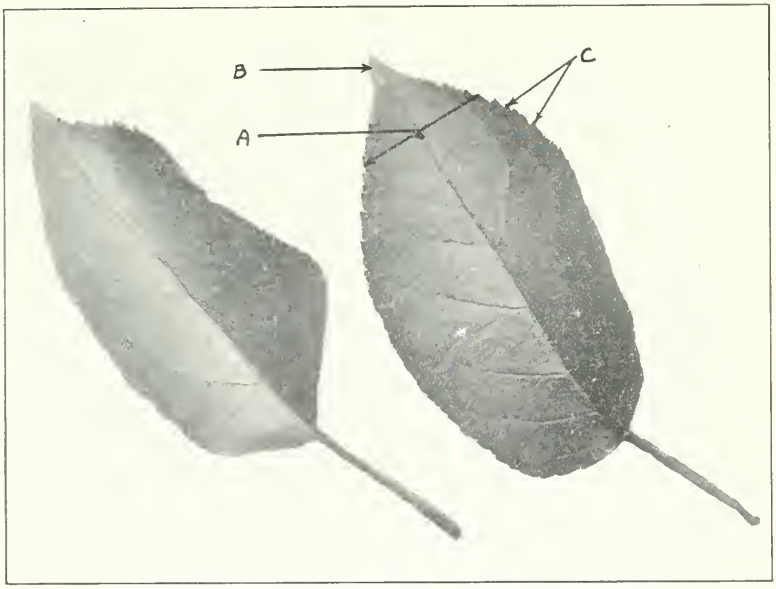

Fig. 10. ARKANSAS (Mammoth Black Twig). Apex rather narrow (A), tip distinct (B); serrations sharp and distinct (C). One of the Winesap group. See p. 84 and 85.

Fig. 11.—DELICIOUS. Blade medium size, apex narrowing to point (A), partly folded (B); serrations moderately sharp, coarse and rather irregular (C). Tree medium size; bark dark olive; shoots dark reddish, irregular. Leaves rather stiff with little pubescence.

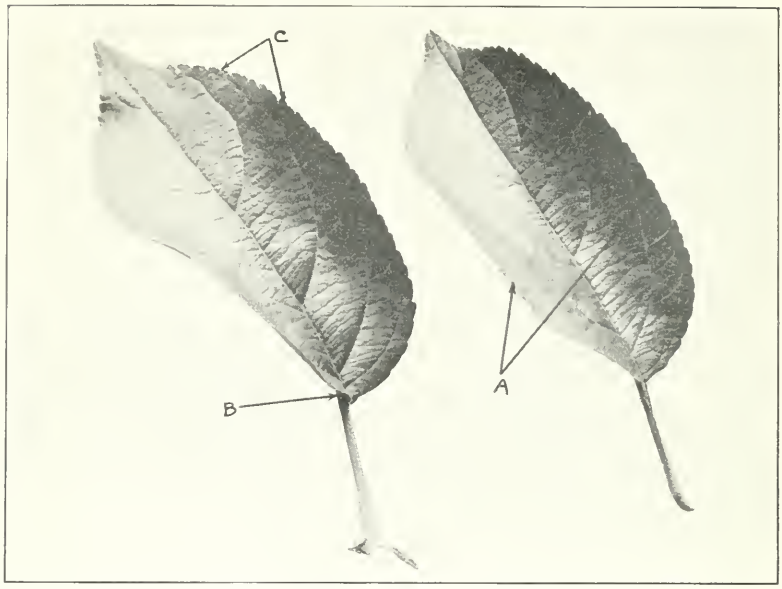

Fig. 12—WINTER BANANA. Blade medium size, rather long and narrow, folded (A), midrib bent at base (B); serrations rather dull and shallow (C), often double. Tree tall, moderately spreading; shoots yellowish.

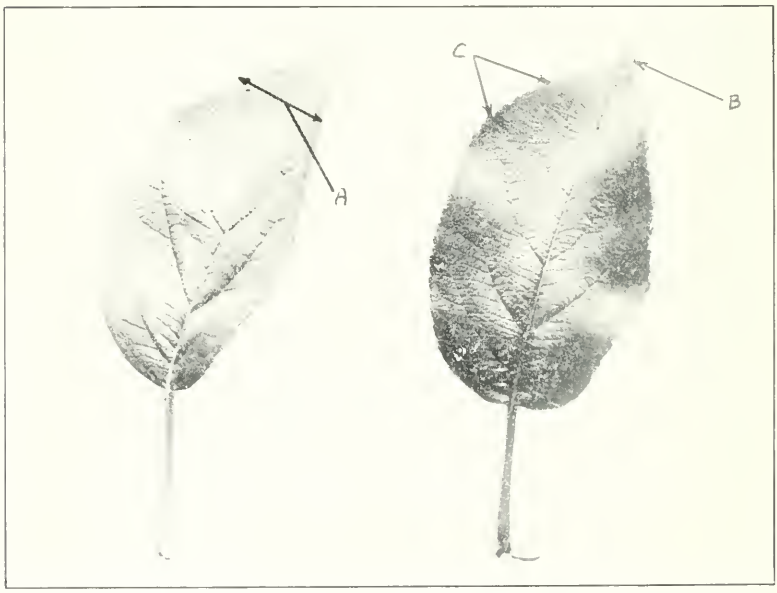

Fig. 13. MAIDEN BLUSH. Apex narrow (A), tip distinct (B); serrations rather fine, shallow and irregular (C). Resembles somewhat the Winter Banana.

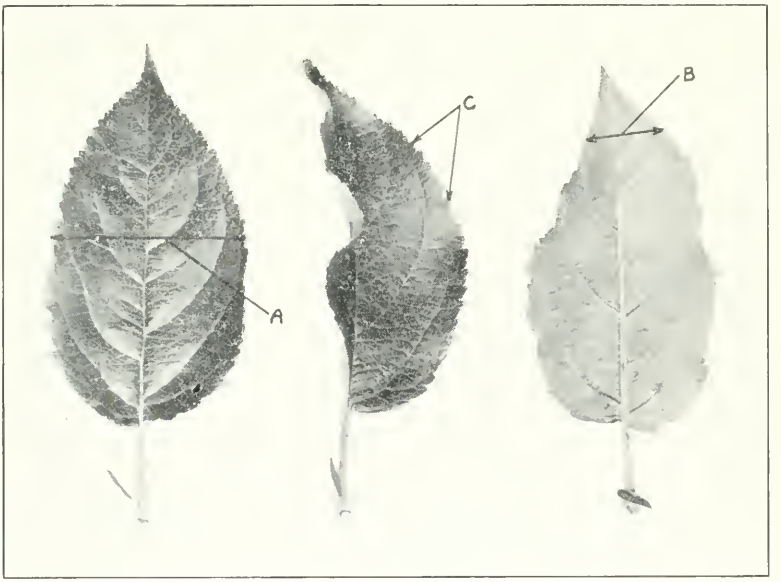

Fig. 14.—RAMBO. Blade rather narrow (A), apex narrow and pointed (B), serrations moderately dull and fine (C). See p. 84 for discussion of other characters.

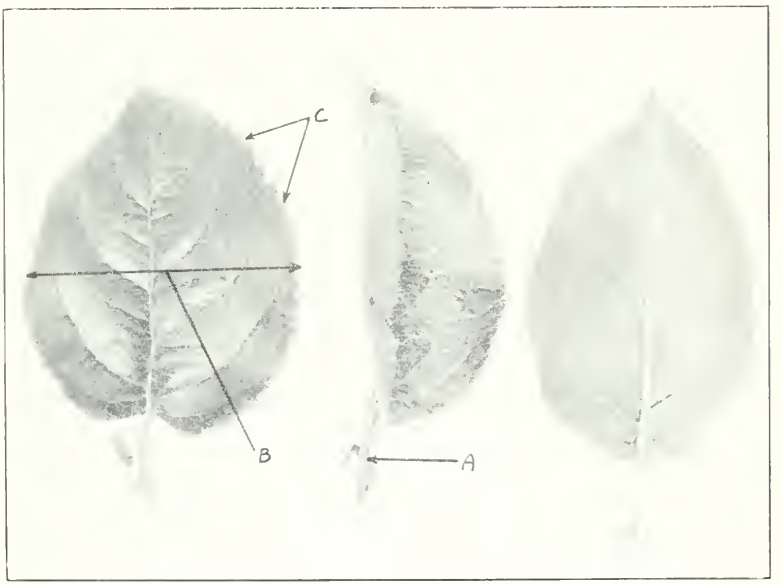

Fig. 15.—SUMMER RAMBO. Petiole short (A); blade broad (B); serrations coarse and rather sharp (C). Sometimes confused with Rambo. See p. .....

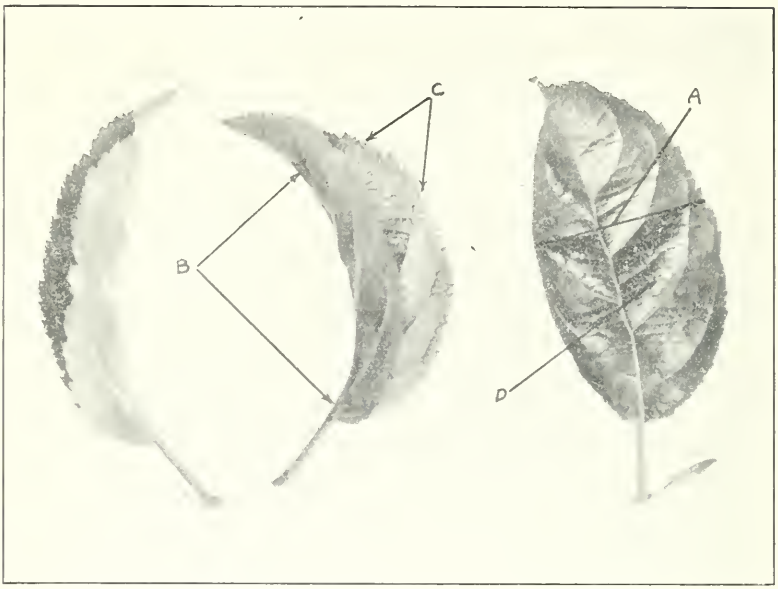

Fig. 16.—ROME BEAUTY. Blade rather narrow (A), much reflexed (B), serrations sharp and irregular (C), texture coarse (D). Tree medium; shoots rather narrowly upcurving; bark reddish.

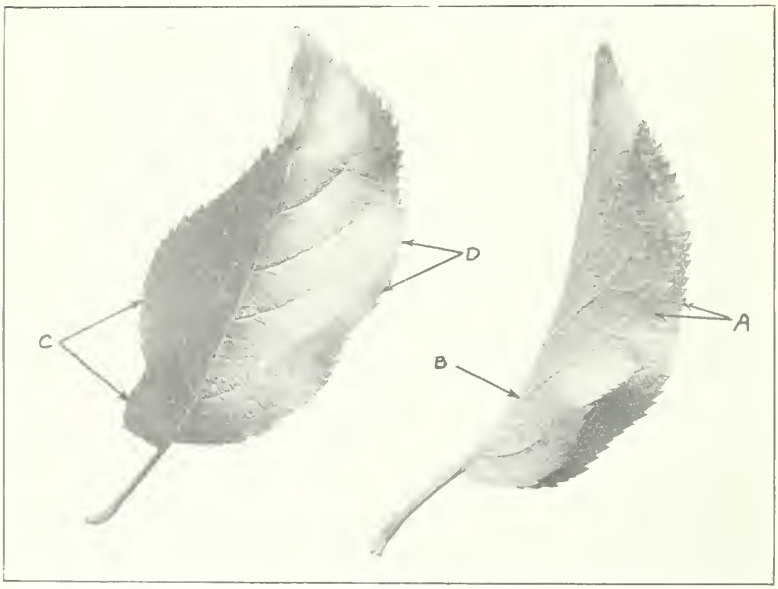

Fig. 17. GRIMES. Blade medium size, folded (A), reflexed (B), and waved (C); serrations sharp, regular and distinct (D). Tree tall; shoots dark reddish; leaves medium green with little pubescence.

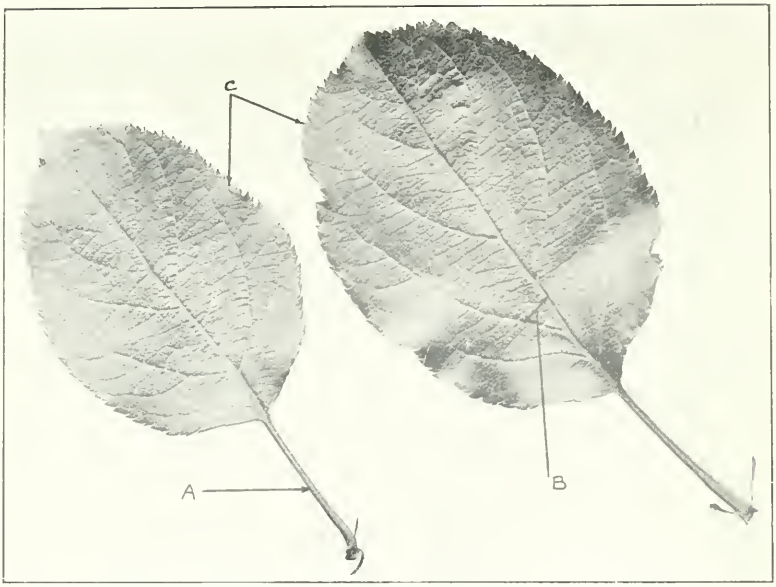

Fig. 18.—RHODE ISLAND GREENING. Petiole long (A); blade large, flat, deep clear green, vein angle sharp (B); serrations very sharp, deep and distinct (C). Tree large; shoots stout, spreading; midrib sometimes reverse curved; smooth.

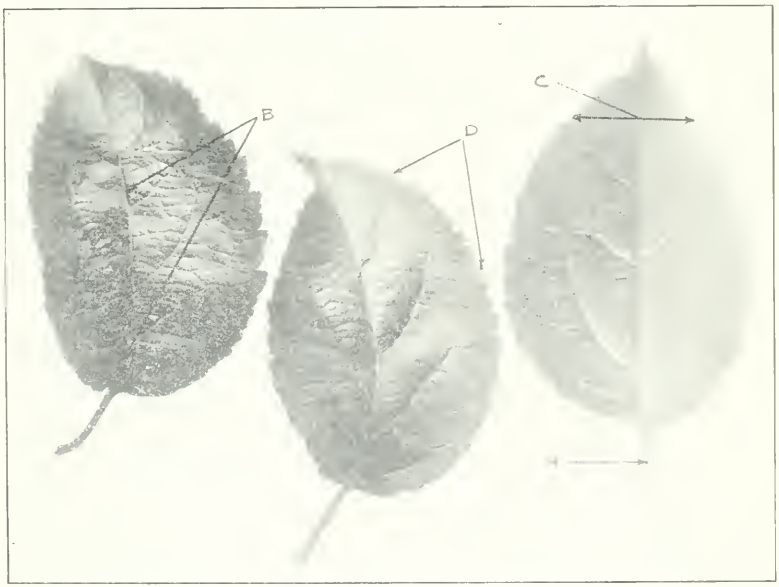

Fig. 19.—NORTHWESTERN GREENING. Petiole short (A); blade reflexed (B), narrowing to apex (C); serrations coarse, dull, and irregular (D). Very different from Rhode Island Greening. Tree rather tall.

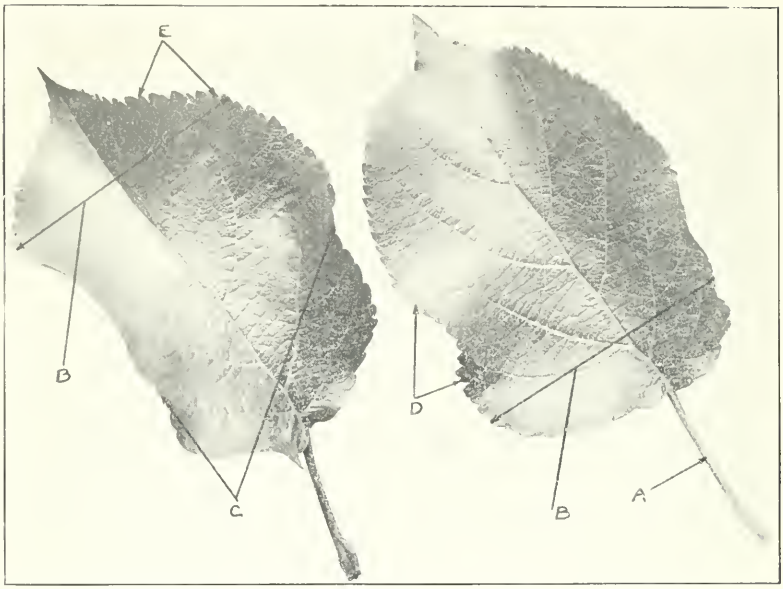

Fig. 20.—OLDENBURG (Duchess). Petiole long (A); blade above medium to large, broad at base and apex (B), somewhat folded (C), and waved (D), serrations moderately sharp and irregular (E). Near the middle of the right half of the left leaf is seen one of the depressions peculiar to this variety. Shoots stout, upcurving, dark reddish.

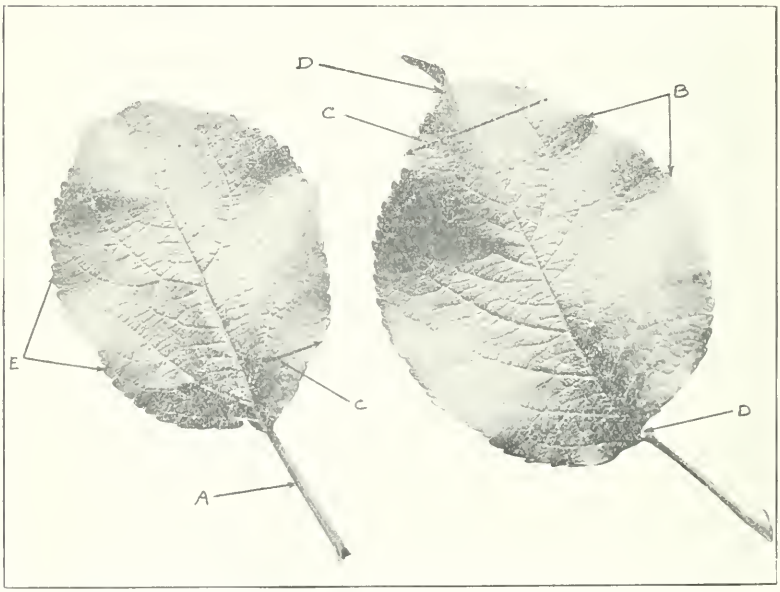

Fig. 21.—WEALTHY. Petiole long (A); blade moderately large, flat, with waved edges (B), narrow at base and apex (C); midrib reflexed or spiral (D); serrations rather dull (E). Tree tall; shoots rather slender; lenticels many, occasionally elongated; leaf texture coarse or pebbly.

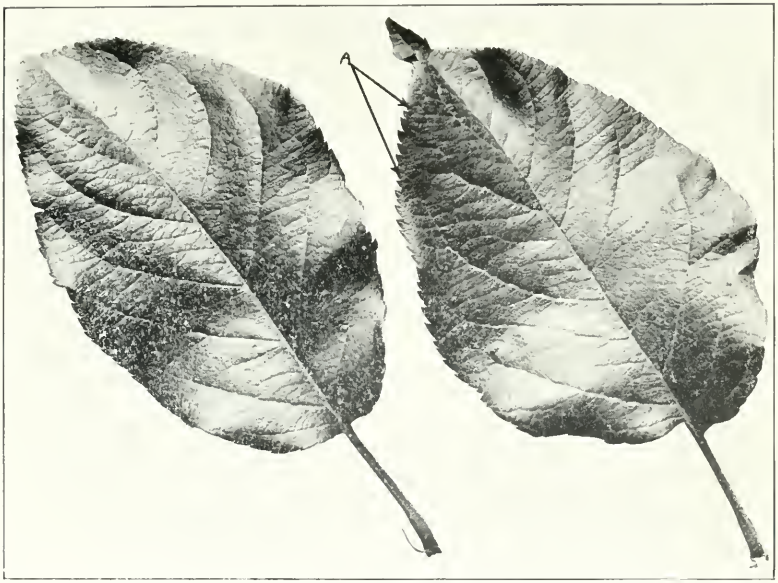

Fig. 22.—NORTHERN SPY. Blade large, somewhat folded and waved, upright, often somewhat reflexed; serrations sharp, often curved (A). Tree rather small; shoots slender, upright, with many distinct lenticels.

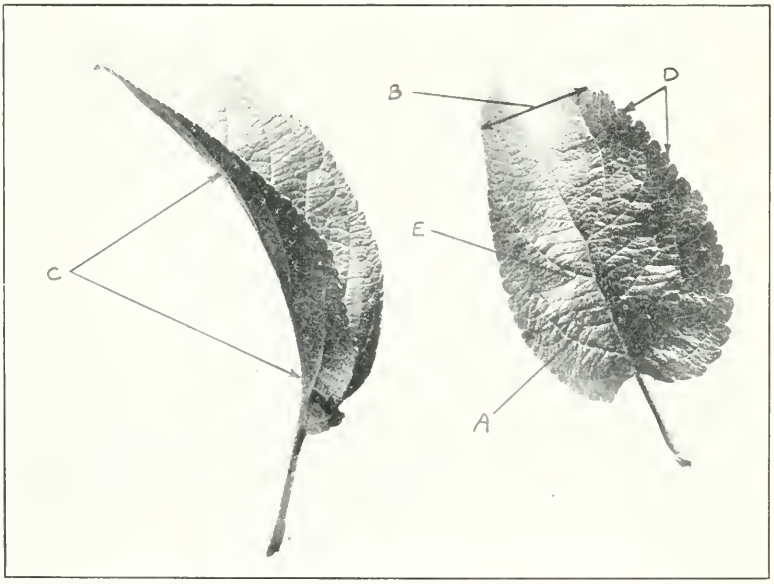

Fig. 23.—YORK IMPERIAL. Blade broad at base (A), narrowing to apex (B), and reflexed (C); serrations dull (D); texture coarse (E). Tree rather short and stocky.

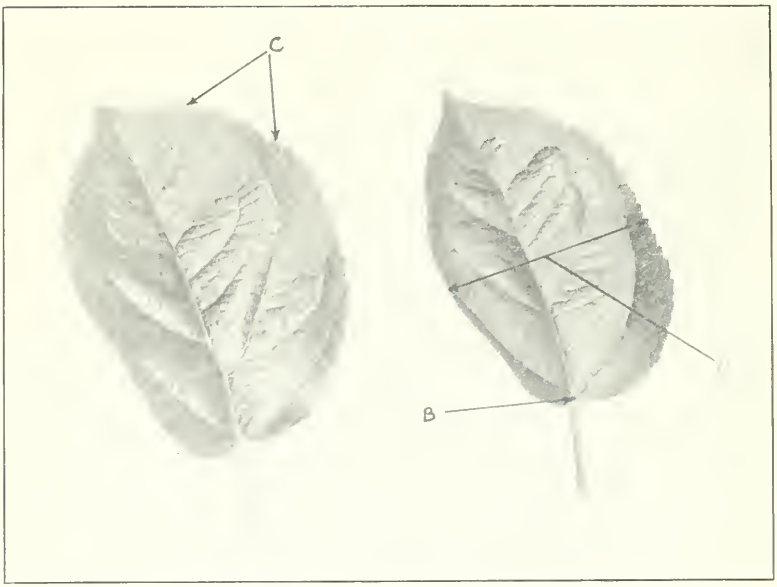

Fig. 24.—EARLY McINTOSH. Blade broad and slightly folded (A), slightly reflexed (B); serrations rather dull and irregular (C). One of the McIntosh group. See p. 85.

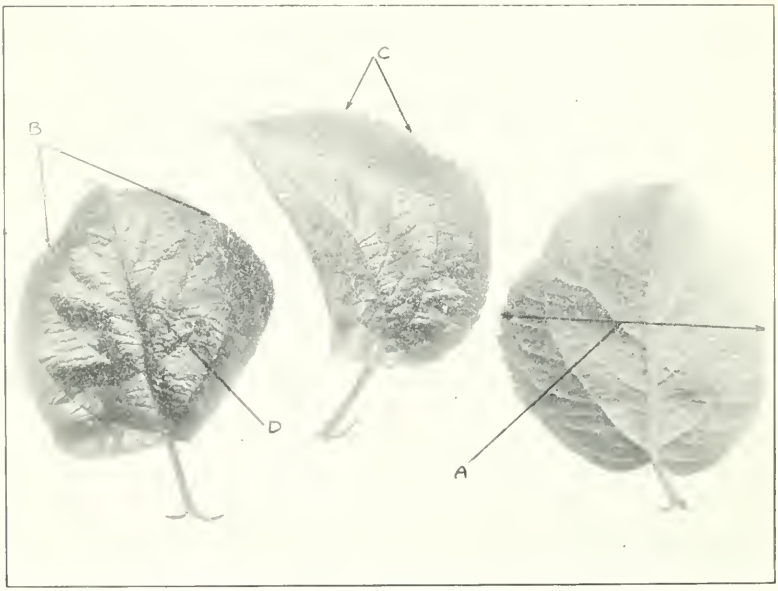

Fig. 25.—MACOUN. Blade very broad (A), folded near edge (B); serrations rather sharp (C); texture very coarse (D). Tree rather stocky. A McIntosh seedling. See p. 86.

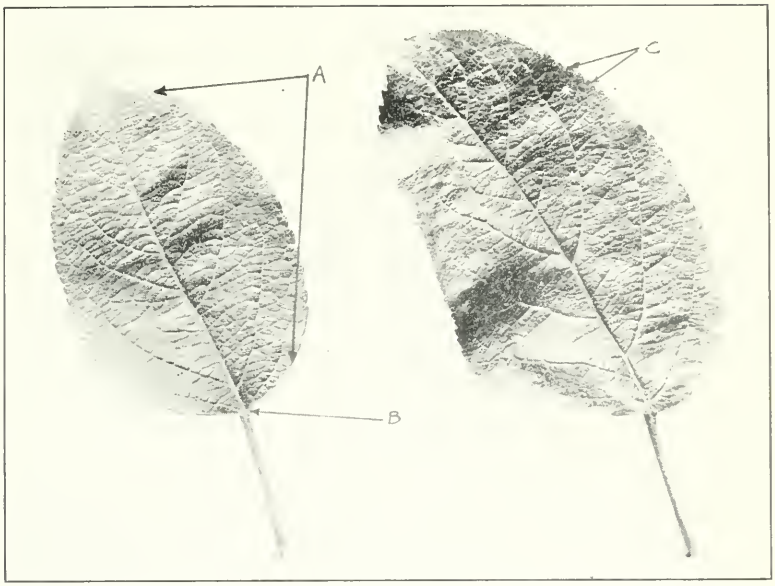

Fig. 26.—CORTLAND. Blade rather long (A), base not heart shaped (B); serrations shallow, regular, only moderately sharp (C). One of the McIntosh group. See p. 85.

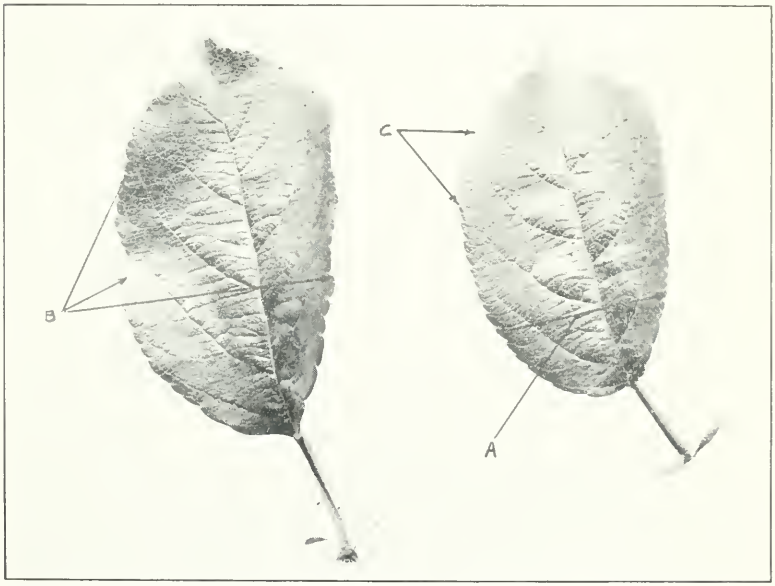

Fig. 27.—FAMEUSE. Blade medium and narrow at base (A), slightly folded and waved (B); serrations moderately sharp (C). Tree tall; shoots rather slender, dark reddish. Leaf texture less rough than McIntosh.

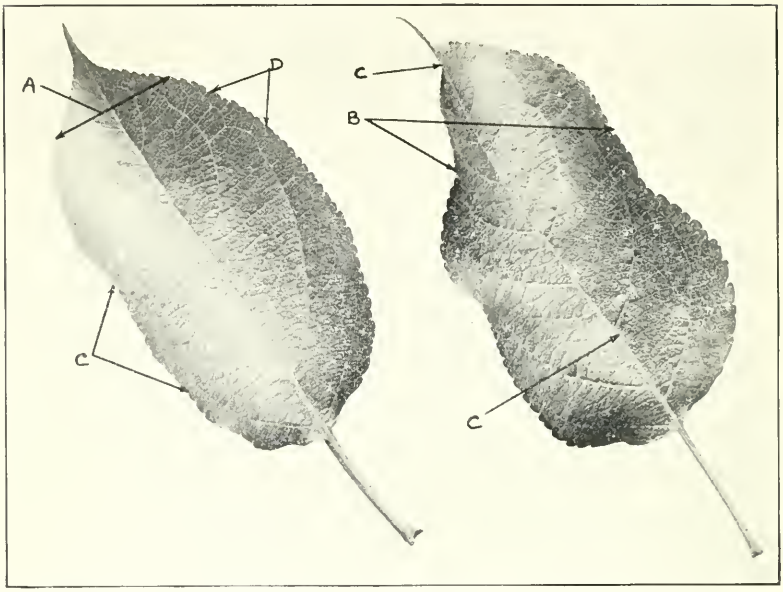

Fig. 28. YELLOW TRANSPARENT. Blade medium size, rather broad at base and narrow at apex (A), more or less folded (B), more or less waved and often spiral (C); serrations rather dull, shallow and quite regular (D). Tree medium; bark yellowish; shoots rather upright, slender, reddish. Leaves somewhat yellowish green, pubescent.

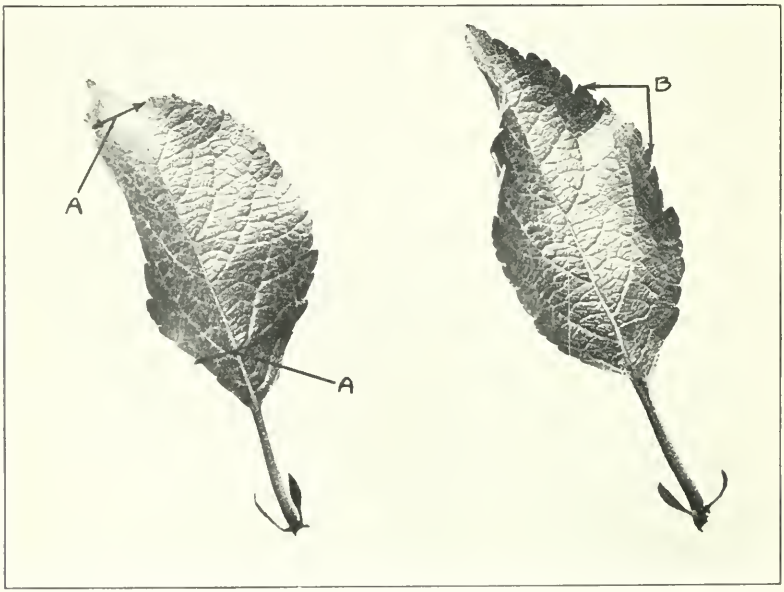

Fig. 29. JONATHAN. Blade very small, more or less folded, sometimes reflexed, narrow at base and apex (A); serrations moderately sharp, coarse, and irregular (B). Tree small, shoots very slender. Leaf texture coarse, pubsecence abundant and coarse.

The Detection of Mixture in the Nursery Row

It has been the observation of the writers that practically all nurseries contain occasional mixtures in the row. Many of the varieties are practically or entirely free from stray trees, but in at least a few, one may find odd varieties mixed in. In budded stock stray varieties usually occur in groups of about five to ten representing the buds from a single bud stick, but in grafted trees strays are more apt to occur as single trees and so closer observation is required to find them.

Some nurserymen say they eliminate all these odd trees when the stock is being put in storage, graded and shipped. No doubt a great many are discovered for many nursery workers become very expert in recognizing varieties as they handle them in storage. Yet some varieties are difficult to distinguish when the trees are in the dormant condition; and the fact that so many misnamed trees reach the fruit grower is good evidence that many escape observation at such times.

It is impossible or at least impracticable to prevent stray trees from getting into the nursery rows. Even trees propagated from bearing trees" have been found to contain mixtures. The only way to eliminate misnamed trees from the nursery row is to go over the rows carefully when the trees are in foliage. Where mixtures are known to exist or are strongly suspected, several examinations at different times during the summer may be desirable, for some mixtures are more easily seen at one stage of development, others at a different stage.

Often the first thing that catches the eye and raises the suspicion of mixed varieties is a difference in size or form of the top. The odd variety is taller or shorter, or it is more spreading or more upright. In many cases it is a different appearance of the foliage. The leaves of the odd trees may be either more or less folded, thus showing more or less of the grayish under surface; or the leaves are larger or smaller or differ in the shade of green; or the surface may have a different texture.

Such differences as are suggested above are, if at all well marked, comparatively easy to detect. Most of the bad mixtures found in practical experience in the nurseries are not so easy. This is especially true of certain common and persistent mixtures as those of varieties of the Winesap group. In these more difficult cases attention should be directed not only to the size and form of the top and the general appearance of the foliage, but also to the leaf serrations, the amount of pubescence, and the number and nature of the lenticels. It is also helpful to compare bark color of the trunks. Color characters are somewhat uncertain, being much affected by growing conditions and stage of development or maturity; but a positive difference of bark color among trees in a single row, especially of a group of trees representing a single bud stick, is pretty good evidence of a mixture.

Before concluding that an odd-appearing tree is a different variety, one should ask himself whether the difference can be accounted for in any other way. This is especially true in the case of a single tree in a row of grafts. This difference may be due to mechanical injury, to insect injury such as lice or leaf hoppers, or to disease. If these possible causes of the difference can be excluded, one should next look for intermediates. If the tree in question is of the same variety as the rest of the row, it should be possible to find

trees that are intermediate in appearance and it will be difficult to say which variety they are. If, on the other hand, one can find no intermediate forms, it is safe to say that a mixture has been found. Usually other trees like the stray will appear on further examination.

Atmospheric conditions are of some importance in examination of mixtures in the nursery. The best condition is when the sun is lightly clouded over and casts no strong shadows. Under such conditions many varietal differences show up best. If the sun is shining it is well to face away from the sun so that its light comes from the rear onto the trees and is reflected back to the eye.

The Age of the Tree

Nursery trees are classed as one-year and two-year trees. Some so-called two-year trees are really three years old, having been cut back severely at two years old and nearly all the one-year growth removed. Such trees grow a new top during the following summer and can be distinguished from true two-year-old trees only by rather careful observation. So far as variety identification goes they may be classed with two-year trees.

Identification of one-year trees must depend solely on leaf and bark characters and the size of the tree. In many cases a group of trees of an odd variety are shorter or taller than the true variety or they are more slender or more stocky. Uninjured leaves on these one-year whips are very characteristic in size, serration, texture and pose. The color of the bark, the lenticels and often the buds and general characteristics of node and internode are distinct and characteristic of the variety. A stray tree or more especially a group from a single bud stick can be seen from a considerable distance. It is scarcely more difficult to identify varieties from one-year whips than from older trees.

In two-year trees there are present the additional characters of branch angle and the entire growth habit of the variety not seen in one-year trees. Also the shoulder or point of union of the branch and main axis often shows characteristics peculiar to the variety.

With increasing age of the tree after setting in the orchard, the tree takes on the form of top characteristic of the variety, while the leaf and bark characters of nursery trees still persist though to a less striking degree. Red Astrachan develops a goblet shaped top, while Delicious develops an upright straggling form. Wagener takes on a very narrow upright form. Jonathan forms a round head, and Rhode Island Greening grows into a low, broad, flat-topped tree. The form of the top may be modified in some degree by the type of pruning followed, but only with very severe and persistent pruning can the characteristic top of a variety be greatly modified. When the tree begins to bear heavy crops, it spreads out and the form is naturally changed; but with bearing, the emphasis changes to the fruit, and tree characters lose their importance for identification purposes.

Common Nursery Mixtures

There are certain variety mixtures that occur more or less frequently and so seem worthy of special mention. These come to light in orchards and so

the fruit grower should be interested in means of identifying these mixtures as early as possible in the life of the tree. It is significant that most of these mixtures are of varieties that are quite similar in appearance when in the dormant stage. They become established in the nursery, are not detected, and are frequently passed on to other nurseries in exchange of buds or scions. It is quite possible to detect them by leaf characters. Here lies the importance of examining nursery rows for mixtures during the growing season. Following are some of these mixtures and the differences by which the stray can be distinguished from the true variety.

McIntosh—Wolf River

This mixture has been widespread, and many thousand Wolf River trees have been sold for McIntosh. It is now nearly, if not quite, eliminated from nurseries, but may still persist in a few cases. Wolf River leaves are oval and distinctly folded and reflexed, while most McIntosh leaves are broad and flat or slightly folded and persist later in the fall. Wolf River serrations are coarser and deeper and often tend to be double. The bark is lighter reddish, and growth more slender. There are other differences, but these are enough to distinguish one from the other. (See Figs. 2 and 3).

Gravenstein—Unknown Variety

Another widespread mixture formerly found in many nurseries, which may still persist, is found in Gravenstein. The apples on the strange variety ripen in the fall and are red-striped, oblate, conic, and ribbed. They become mealy shortly after ripening and are of inferior quality. The variety is readily distinguished from Gravenstein by its broad, roundish leaves with deep, rather sharp serrations. Its identity is unknown. (See Figs. 6 and 7.)

Baldwin—Unknown Variety

Another mixture which has been found by the writers in a half dozen or more widely scattered nurseries, is an unknown variety among Baldwins. The apple is oblate and green, often with a blushed or obscurely splashed cheek. It is of inferior quality, never ripens properly in this region, and often drops in early September. The nursery tree closely resembles Baldwin, but is characterized by the following differences.

1. The bark is more reddish and the shoots of more slender, spreading growth.
2. The leaf is more distinctly folded and waved, and the folding is nearer the midvein. The leaves are more often waved. This is the difference that is most apt to catch the eye when this mixture is encountered. Often the leaf is softer, less rigid than Baldwin. In the fall they do not strip so easily.
3. There are more short spurs with folded, waved leaves at the top of the trunk at the base of the main branches.
4. The leaves at the tips of the upright shoots are more folded and the surface is duller and less shining and has a slight bluish cast.
5. The foliage often shows scab spots which are very rare in Baldwin.

Not all these differences appear in every case, but taken together they furnish a safe basis for detecting this mixture. (See Figs. 4 and 5.)

Duchess— Unknown Variety

This mixture has been found in a very few cases. The writers have not seen the fruit of the stray variety, but the tree is readily distinguished from Duchess by the sharper, more distinct serrations of the leaves. The leaf surface is duller with a slight bluish cast. It lacks the depressions in the leaf (about the size of hail marks on fruit) which are characteristic of Duchess. (See Fig. 20.) Duchess often shows a distinct rosette of leaves as terminal growth ceases, and these are not evident in the unknown variety.

Winter Banana—Maiden Blush

These varieties closely resemble each other and are sometimes found mixed in nursery rows. Maiden Blush trees are often less tall and of more narrow upright growth, but the most distinct difference lies in the leaf serrations. Those on Winter Banana are coarser, duller and often show a distinct tendency to doubleness. Maiden Blush serrations are finer, more regular and rather sharp. Maiden Blush leaves are generally smaller, and the leaf surface shows a slight bluish cast not seen in Winter Banana. (See Figs. 12 and 13.)

Rambo—Summer Rambo

There seems to be some confusion among nurserymen over these two varieties arising, no doubt, from the similarity of the names. When grown side by side the two varieties are seen to be quite distinct. Summer Rambo is comparatively tall, vigorous and spreading, while Rambo is shorter and more upright in growth; also the lenticels are smaller. The leaf of Summer Rambo is larger and more coarsely waved, with sharper, more distinct serrations. The Rambo leaf is narrower, especially toward the apex. (See Figs. 14 and 15.)

The Winesap Group

The Winesap group of varieties is one of the most clearly defined to be met with. It may be variously delimited, but here it may be best considered as including Winesap, Stayman, Arkansas (Mammoth Black Twig), Paragon, Arkansas Black, and Delicious. Mixtures of two or more of these varieties are frequently met with in nurseries.

Arkansas (Fig. 10) and Paragon resemble each other very closely. Although sometimes considered identical, they can nevertheless be distinguished from each other even as non-bearing trees; but Paragon has been studied too little to warrant a statement of distinguishing characters. Often the identity of Paragon met with in nurseries may be doubtful. All the other varieties may be distinguished with reasonable certainty.

Winesap carries an earmark that separates it from all other varieties. This is a small roundish leaf with very coarse dull serrations, shown in Fig. 8. (Fig. 8 was erroneously named Stayman in Bulletin 208.) These leaves may be few, but one or more will most certainly appear on any tree, even a small one. The upper surface of the leaves shows a pebbly texture somewhat

resembling that seen in Wealthy. The smaller size and more slender growth of the tree, its rather dense roundish head, and the few lenticels in the bark serve also to characterize Winesap.

Stayman (Fig. 9) is a much more vigorous variety with longer, stouter shoots growing in an open, upright-spreading form. The buds are larger and more hairy. The pubescence is more abundant and coarser on both leaves and young shoots.

Arkansas (Mammoth Black Twig, Fig. 10) is similar in form to Stayman and often confused with it. It differs in that the lenticels are somewhat less abundant and finer, resembling the others of this group rather than the Stayman. The leaf is somewhat broader with a more distinct tip and often darker green and less hairy. The leaf serrations are usually a little sharper and more distinct.

Arkansas Black is a somewhat smaller, less vigorous variety than Arkansas and of more slender upright growth; the leaf is quite distinctly folded and somewhat waved, while Arkansas leaves are nearly flat or only slightly folded, with very little or no waving.

Delicious (Fig. 11) is quite distinct from the other varieties here included in the Winesap group but is sometimes found mixed with them, more likely with Stayman or Winesap. It is variable in habit of growth but is likely to be more upright, especially with vigorous trees, and is always of a straggling, irregular type of growth. The bark is darker in color than Stayman. The leaves are dark green and have less pubescence than other varieties of this group. The serrations are moderately sharp to rather dull, somewhat like the variations in Winesap but not reaching the extremes seen in that variety.

Anyone desiring to learn to distinguish the varieties of this group should study trees known to be true to name and learn to recognize the differences here given and others of perhaps less signficance. Careful observation is necessary, but with it these varieties may be distinguished with reasonable certainty.

The McIntosh Group

The McIntosh is now one of the most important varieties found in nurseries. Its excellent qualities have led to its use in breeding work, and as a result several varieties are appearing in nurseries and orchards, of which McIntosh is one parent. Probably others will appear. The question arises whether these related varieties may be confused with each other and with the McIntosh. The writers have studied nearly a dozen McIntosh seedlings and concluded that while these varieties do resemble each other and show their relationship to McIntosh, there should be little difficulty in identifying them from the non-bearing trees.

Cortland (Fig. 26) is distinguished from McIntosh by a relatively longer leaf *with a rounded instead of a heart-shaped base.* The foliage shows a lighter green color, best seen when one looks down a row so as to see the growing tips. Many Cortland leaves are folded downward instead of upward as is common in McIntosh and many other varieties. The old bark of Cortland is darker than that of McIntosh. The lenticels are often somewhat more abundant.

Early McIntosh (Fig. 24) shows characters from each of its parents, McIntosh and Yellow Transparent. Compared with McIntosh, the shoots are

usually longer and, toward the base of new shoots, less reddish showing some blending with yellowish. The lenticels are fewer and often some are elongated. The leaves are more folded and show some waving similar to Yellow Transparent. The serrations are less dull, more irregular, and more distinct.

Macoun (Fig. 25) is a more stocky tree than McIntosh, with few stout, rather narrowly upcurving branches. The leaves are broad, even roundish, and of a notably rough or rugose texture. The serrations are sharper than those of McIntosh.

Milton has shoots more slender than McIntosh and the serrations are much sharper. The leaves are less folded, and the texture smoother than McIntosh and much smoother than Macoun.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 275 June, 1931

Planning the Farm Business on Three Dairy-Fruit Farms in Massachusetts

By R. L. Mighell

Farm adjustments made by individual farmers often serve as valuable guides to others in similar situations. This study analyzes the farming systems and describes in detail some practical adjustments already adopted or planned on three Massachusetts dairy-fruit farms.

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SUMMARY

1. The three Massachusetts farms in this study are referred to as Farms A, B, and C, and the operators as Mr. A, Mr. B, and Mr. C, respectively. These are actual farms, and the data used in the analysis were secured from records kept on these farms.

2. Farm A is a one-man unit with 11 cows and 150 bearing apple trees. The operator has considered various plans for improving his earning power. After a careful analysis of the possibilities, he now plans to buy a milking machine and enlarge the dairy herd to 16 cows. He has enough barn room and can produce enough hay and silage for this number of cows.

3. Farm B is a two-man unit. There are 16 cows and 250 bearing apple trees. The operator also keeps a small poultry flock and raises young stock for sale. His long-time farm program will finally result in a much larger bearing orchard. In the meantime, however, the net farm income must be increased in some other way. A careful analysis of the business finally convinced the operator that the most profitable procedure would be to increase the dairy herd to 24 cows. To secure enough barn space and roughage feed, he plans to dispose of all the young stock and depend on purchased replacements. A budget worked out on this basis shows a substantial increase in net returns.

4. Farm C is a large three-man unit with 21 cows and 1000 bearing apple trees. The outstanding achievement on this farm has been the careful planning of an efficient labor program. Seasonal work is fitted together to avoid conflicting periods. Individual jobs have been analyzed to develop labor-saving methods. Only relatively minor adjustments in organization and operation are planned for the future.

PLANNING THE FARM BUSINESS ON THREE DAIRY-FRUIT FARMS IN MASSACHUSETTS

By R. L. Mighell, Assistant Research Professor of Farm Management

This study presents an analysis of the farming systems followed by three neighboring Massachusetts farmers. All three are dairymen and apple growers. Although they have many problems in common, the differences in their farm organizations are numerous. Their fixed resources of land and buildings are quite different. The orchards differ in size, age and varieties of apples. The dairy cows vary in number and production. Perhaps most important of all are the differences in the personal capacity[1] and efficiency of the three operators.

The personal factor is one of the most difficult to analyze. In the case of these three farmers it is probable that Mr. C, who has the largest farm, has both more capacity and more efficiency than either Mr. A or Mr. B, the other two farmers. Mr. A, operating the smallest business, shows the least capacity but possibly is more efficient than Mr. B. These judgments are based on the past record of each farmer and may not be an indication of what each is capable of doing under changed conditions. But in any event, every farmer must take his personal abilities into account in planning changes in his farm organization. If he undertakes more than he has capacity for managing, he may make less money than by operating on a smaller scale. He must also consider all his fixed resources and not be influenced too much by other farmers, who may be operating under entirely different conditions. A neighbor with ten acres of silage corn may be able to buy a corn binder, when he, himself, can not afford one for four acres. Some dairymen may profitably fertilize pasture, while others with more pasture land cannot afford to do so.

Since each of the three farms in this study represents a different type of business, the analysis is developed separately for each individual case and comparisons are drawn only for the purpose of showing how the various changes work out under the different conditions. Some of the adjustments discussed are already adopted or under way, while others are proposed.

FARM A—A SMALL DAIRY-FRUIT FARM

Farm A is a small one-man unit with 11 cows and 150 bearing apple trees. The operator, Mr. A, is a young man who has been farming about ten years. For the past few years he has had difficulty in making enough money from the farm to meet his family expenses. He is very much interested in working out changes or adjustments in his present farming system and methods of operation which will increase his net income. Before outlining the adjustments which he has considered and is planning to make, the present farming system will be described.

[1] The term "capacity," is used in the economic sense, referring to the size of business which the farmer is capable of managing. Efficiency is the ratio between the value of the farm production and the value of the cost factors used. Both capacity and efficiency are necessary to secure the highest farm profit.

The Present Farming System

Tables 1 and 2 show the present farm plan just as it was in 1929. Table 1 shows the acreage and production of each crop and the materials used. Hay occupies the greater part of the crop acreage. The apple orchard takes up only 8 acres out of the total of 38 in crops. One acre of potatoes is grown.

Table 1.—Acreage and Production of Crops and Materials Used on Farm A.

	Acres	Production	Materials Used		
			Seed	Fertilizer	Spray
Apples, 150 trees	3	509 bu.			.....[2]
Apples, non-bearing 150	5				
Hay	26	47 tons			
Oat Hay	3	3 tons	7.5 bu.		
New Seeding	3[1]		37.0 lbs.		
Potatoes	1	125 bu.	10.0 bus	1 ton	.....[3]
Total Crops	38				
Pasture	109				
Farmstead	3				
Total Farm Area	150				

[1] Seeded in the oats—mixture 28 lbs. timothy, 4½ lbs. red clover, 4½ lbs. alsike.
[2] 34 lbs. lead arsenate, 1 gal. blackleaf 40, 40 lbs. dry lime sulfur, 32 gals. lime sulfur.
[3] 50 lbs. lime, 40 lbs. copper sulfate, 4 lbs. Pyrox, 16 lbs. lead arsenate.

Table 2 gives the average number of each kind of livestock on hand during the year and the amounts of feed used. The silage fed is from the previous year's crop, as Mr. A decided not to grow silage in 1929. Because of the dry summer weather in this year, considerable roughage had to be fed to supplement the pastures. In ordinary years there would have been a surplus of hay left over. Commercial dairy grains are fed to the cows and young stock.

Table 2.—Pounds of Feed Used by the Following Numbers of Livestock on Farm A.

Feed	Horses 2.0	Cows 10.8	Heifers 2.7	Calves 3.4	Bull 1.0	Poultry 27.2	Totals
Dairy Ration		23,100	600	100	900		24,700
Calf Ration			150	950	100		1,200
Oats	2,080						2,080
Cracked Corn	1,450					1,450	2,900
Whole Milk				2,049			2,049
Skimmilk Powder				200			200
Scratch and Mash						300	300
Silage		32,946	4,687		2,367		40,000
Hay	15,364	59,764	7,820	8,612	8,439		99,999

The average production of the cows is 6600 pounds of milk testing about 3.5 per cent. This is a good average for a young dairy herd made up of grade Holsteins.

The statement in Table 3 shows the earning capacity of the present organization based on Mr. A's 1929 records. More than half the cash receipts come from milk sales. Apples represent about a third of the total. Work off the farm is the largest of the minor receipts. The total cash receipts are a little over $3000.

TABLE 3.—FINANCIAL RETURNS FROM PRESENT ORGANIZATION—FARM A.

Receipts		
Whole milk 65,510 lbs. @ $2.60	$1703	
9 calves	76	
Apples, 509 boxes @ $1.70	865	
Potatoes 100 bu. @ $1.50	150	
Work off the farm	168	
Wood, and miscellaneous	59	
Total Receipts		$3021
Expenses		
Grain	$844	
Labor hired	42	
Veterinary and medicines	4	
Bedding, salt and other livestock expense	22	
Ice	17	
Seeds	12	
Seed potatoes	17	
Potato fertilizer, 1 ton	45	
Spray materials	30	
Truck registration, fuel and repairs	170	
Telephone	33	
Taxes	103	
Repairs to buildings and equipment	36	
Total Expenses		1375
Net Return Above Expenses		$1646

On the expense side purchased grain accounts for over half the total. Taxes and truck expense are the largest of the smaller items. The total expense is $1375, leaving a net return above cash expenses of $1646. The farm land and buildings together with livestock and equipment are valued at $14,000. If interest at 5 per cent is computed on this valuation, an interest charge of $700 is obtained which, deducted from $1646, leaves $946. This may be considered as the net return to Mr. A, for his labor and management. Of course, the farm also furnishes milk, eggs, potatoes, apples and other products, as well as a home for his family.

This financial return is small when it is considered that only a minimum of expense for repairs and upkeep was incurred during the year. No fertilizer

was applied to the orchard or hay land. No allowance has been made for depreciation on the motor truck and other machinery and no provision has yet been made for the purchase of new equipment.

Possible Adjustments in the Present Plan

Mr. A has considered various adjustments and changes in organization which might increase his income more than his expenses. Some of his neighbors have succeeded with chickens. Mr. A plans to keep more poultry as soon as his two small boys are old enough to care for the flock. At present he does not care to go to the expense of building a new poultry house. Another serious difficulty would be the labor conflict in the spring between the work on potatoes and apples, and the young chickens.

He has also thought of growing a larger acreage of potatoes as a supplementary cash crop. If he were to do this, however, it would be necessary to buy a potato planter and digger and hire extra help both at planting time and at harvest. At present he borrows machinery from a neighbor and does the work on the one acre of potatoes alone. The potato harvest would also conflict with apple harvest. He estimates that potatoes would add very little to his net income.

Another possible change would be to increase the number of cows and hire a man throughout the year to do the extra work. Mr. A has barn room for about five more cows, and can raise enough more roughage to feed this number and the extra young stock needed for replacements. A few years ago he tried making this adjustment. The following statement summarizes about what happened.

Table 4.—Extra Receipts and Expenses with Five More Cows and a Hired Man—Farm A.

Extra milk, 5 cows, 33,000 lbs. @ $2.60	$858	
Extra calves sold	24	
Extra work off the farm	50	
Total Extra Receipts		$932
Extra purchased feed	$325	
Extra hired labor	600	
Total Extra Expenses		925
Net Return Above Extra Expenses		$ 7

In this statement the average production per cow and the price of milk are adjusted to the same production and price as in the present organization. The difference between extra receipts and expenses is very small. After trying it out, Mr. A preferred to change to his present organization and avoid the nuisance of having the extra man around when there was not enough work for him. Had it been possible to add still more cows, it would have been profitable, but this could not have been done without more barn room and provision for more roughage than the farm was capable of producing.

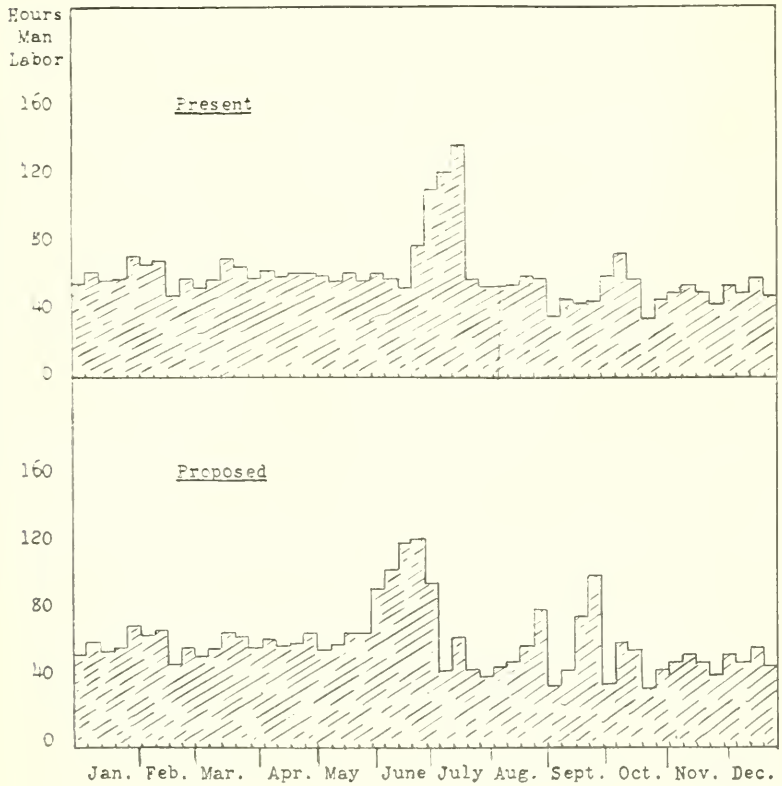
Proposed Reorganization Plan—More Cows and a Milking Machine

A careful analysis of all aspects of the business finally resulted in the suggestion that Mr. A is now contemplating. He plans to buy a milking machine and make such other changes as will enable him to keep at least 16 cows without hiring additional regular labor. By using the milking machine and planning the barn chores more carefully, it is estimated that he can easily do the regular daily work in the same time that he now spends on 11 cows, milking them by hand.

It is further planned that potatoes be discontinued and the time and land be used for silage corn. An estimated yield of 10 tons per acre for 4 acres will give a production of 40 tons of silage which is about the capacity of the present silo. By cutting hay several weeks earlier it will be possible to secure a higher quality of hay. This together with silage should provide sufficient roughage for most seasons. Since more than the usual amount of roughage was consumed in 1929, there is normally some surplus with the present system.

Figure 1 shows the distribution of man labor on this farm at present and

Figure 1.—Distribution of Man Labor by Weeks on Farm A for Present and Proposed Organizations.



under the proposed system. Notice that the chief differences are in June and September. It will be necessary under the new plan to hire a man for about five weeks in June for haying and cultivating, and perhaps ten days in September for silo filling. At present an extra man is hired for part of July. These are the principal changes in the labor needed by the new organization. The financial statement for this proposed system is shown in Table 5.

TABLE 5.—ESTIMATED FINANCIAL RETURNS FROM PROPOSED ORGANIZATION FARM A.

Receipts		
Whole milk 101,600 lbs. @ $2.60	$2642	
12 calves	100	
Apples 509 boxes @ $1.70	865	
Work off the farm	170	
Total Receipts		$3777
Expenses		
Grain	$1155	
Labor hired	75	
Veterinary and medicine	8	
Bedding, salt, etc.	30	
Ice	25	
Seeds	15	
Spray material	25	
Truck registration, fuel and repairs	170	
Telephone	33	
Taxes	110	
Repairs to buildings and equipment	36	
Milking machine (operating expenses and depreciation)	80	
Total Expenses		1762
Net Return Above Expenses		$2015
Net Return Over Present Organization		$ 369

Milk receipts are estimated on the basis of sixteen cows at the present average production of 6600 pounds. (Milk fed and used in the house is not included in sales.) Three extra calves are sold and other receipts are left as at present.

The expense on purchased grain has been figured for an average of five heifers, six calves and one bull. This is slightly more young stock than at present in order to allow for replacement of the additional cows. Amounts of grain fed have been estimated at the present rate of feeding per head for each class of stock. Hired labor expense has been increased to $75 to allow for additional help in haying and at silo filling. A charge of $80 is made on the milking machine to cover operating expense, and interest and depreciation on the investment. This charge may vary somewhat, but based on an initial cost of around $300 and operating expenses on some neighboring farms it is probably very liberal. Several of the minor expenses are increased slightly and potato expenses are, of course, omitted.

The total expense is then $1762, or nearly $400 more than under the present plan. Receipts have increased nearly $800, however, so that the net return is $2015. This makes a net gain of $369 above the return from the present organization. This may seem a rather small increase, but it must be remembered that it represents a large increase in proportion to the amount of money that Mr. A now has left after figuring interest on his investment. If his labor and management return was formerly $946, it is now approximately $1300,[2] or about 40 per cent larger.

Effect of Price Changes on Financial Returns

In planning farm reorganizations such as Mr. A is contemplating, it is always necessary to exercise care in estimating future prices. In this case he estimates that milk and grain prices will continue at about the same level as in 1929. If milk prices were likely to decline to approximately $2.00 per hundred pounds with no particular change in prices of grain or other expense factors, there would be much less advantage in making the reorganization.

Table 6 shows the effect of such a change in price. The net farm return on the present organization would be reduced to $1253 and the net return for the proposed organization to $1405. It would still be profitable to make the change. The advantage, however, would be only $152 as compared with $369 increase in return with Mr. A's present estimate of future prices.

TABLE 6.—MILK PRODUCTION, RECEIPTS, AND NET RETURNS FROM PRESENT AND PROPOSED FARM ORGANIZATIONS WITH MILK PRICES AT TWO DIFFERENT LEVELS.

	Present Organization	Proposed Organization	Increase over Present Organization
Milk production, pounds	65,510	101,600	36,090
Milk receipts @ $2.60 per cwt.	$1,703	$2,642	$939
Milk receipts @ $2.00 per cwt.	1,310	2,032	722
Net farm returns @ $2.60 per cwt.	1,646	2,015	369
Net farm returns @ $2.00 per cwt.	1,253	1,405	152

FARM B—A TWO-MAN FARM

The planning and operation of a larger farm often presents certain problems not found on farms the size of Farm A. The 16 cows and 250 bearing apple trees on Farm B represent an odd-sized business. It is too large for one man and not large enough for two men. Mr. B and one married son operate the farm together and are therefore interested in making it a large enough business for both of them. In order to increase the size, they keep a small poultry flock of about 250 birds and devote some attention to raising young dairy stock for sale. Mr. B decided several years ago, however, that the best long-time plan to follow was to set out some apple trees and plan on getting a larger net return from increased apple receipts. It will still be ten or twelve years before he begins to realize much from the young trees

[2] Some allowance should be made for the increase in investment due to the extra cows.

which he then set out. In the meantime he is anxious to increase his income from other sources, if possible.

The Present Farm Plan

Mr. B's present farm set-up is shown in Tables 7 and 8. The figures shown are the actual acreages, numbers of stock and amounts for the year 1929, as shown by records kept by Mr. B. The hay occupies about two-thirds of the crop land. Silage corn and the bearing apple orchard take up the remainder. The young apple trees are set with extra wide spacing in the hay land. As they are still very small, they do not reduce the hay yield much. In 1929 a

TABLE 7.—ACREAGE AND PRODUCTION OF CROPS AND MATERIALS USED ON FARM B.

	Acres	Production	Materials Used: Seed	Materials Used: Fertilizer	Materials Used: Ground Limestone
Apples, 250 trees	7.0	1500 bu.			
Apples, non-bearing 500	10.0[1]				
Hay	22.0	65 tons		2000 lbs[2] 1000 lbs[3]	
Silage Corn	4.5	50 tons	2 bu.		
New Seeding	2.0[4]				10,500 lbs.
Total Crops	35.5				
Pasture and Woods	163.0			500 lbs[5]	
Farmstead	1.5				
Total Farm Area	200.0				

[1] Set in hay land, except 2 acres.
[2] Superphosphate.
[3] Sodium nitrate.
[4] Seeded in corn at last cultivation—mixture 1 bu. timothy, 10 lbs. red clover, 15 lbs. alfalfa, 10 lbs. alsike.
[5] Mixed fertilizer—5-8-7 on about 1 acre.

TABLE 8.—POUNDS OF FEED USED BY THE FOLLOWING NUMBERS OF LIVESTOCK ON FARM B.

Feed	Horses 2.0	Cows 16.5	Heifers 9.8	Calves 7.0	Bull 1.0	Poultry 266.0	Totals
Mixed Horse Feed	5,800						5,800
Fulpail Dairy Ration		37,300					37,300
Fitting Ration			9,400				9,400
Calf Ration				3,000			3,000
Hen Feed						17,900	17,900
Chick Feed						2,200	2,200
Whole Milk				320			320
Skimmilk Powder				186			186
Silage		88,345	18,338	395	2,922		110,000
Hay	17,645	78,435	21,258	7,425	5,238		130,001

production of three tons per acre was obtained. Mr. B uses commercial fertilizer to obtain this high yield. It will not be possible to maintain this production of hay because the yields will tend to decline as the trees become larger.

The amounts of hay and silage consumed during the year as shown in Table 8 are approximately the same as the production. If more stock were kept it would be necessary to buy hay, or feed relatively more of some of the concentrated feeds.

The earning power of the present organization is shown by the financial statement in Table 9. This statement is based on the actual business record for the calendar year 1929, with one or two slight adjustments to allow for inventory differences. Some variation from this record may be expected in other years because of differences in production and prices. However, Mr. B estimates that it is about what he can reasonably expect from his present organization for several years to come.

TABLE 9.—FINANCIAL RETURNS FROM PRESENT ORGANIZATION—FARM B.

Receipts		
Milk 88,143 lbs. @ $2.60	$2292	
4 old cows @ $50.00	200	
4 heifers @ $110	440	
8 calves @ $7	56	
Broilers and fowls	293	
Eggs 2210 doz. @ $.40	884	
Apples, 1500 boxes	3022	
Work off the farm	104	
Total Receipts		$7291
Expenses		
Hired labor	$582	
Grain for cattle	1300	
Horse grain	147	
Poultry feed	553	
Veterinary and medicine	23	
Other cattle expense	32	
Horseshoeing	14	
Baby chicks	122	
Seeds	32	
Fertilizer and lime	158	
Spray material	62	
Apple boxes	250	
Repairs	57	
Auto and truck registration, fuel and repairs	257	
Electricity	118	
Telephone	24	
Taxes	192	
Total Expenses		3923
Net Return Above Expenses		$3368

Receipts from apples and from the dairy enterprise are about equally important if sales of milk and livestock are added together. Poultry receipts, amounting to nearly $1200 are also significant. The total cash receipts are $7291.

Among the expenses, grain for the various classes of livestock is the largest item, amounting to more than half the total. Hired labor is the next largest. The expense for labor includes the regular help of a boy through most of the year as well as extra help for peak loads like apple picking and grading. Other large items are apple boxes, taxes, electricity, and auto and truck expense. The total expense amounts to $3923. This does not include outlay for new machinery, new buildings or other capital investments, which are not considered current expense.

The net return to the farm after deducting the expenses is $3368. No allowance has yet been made for interest on the capital investment. The estimated value of the land, buildings, equipment and livestock is approximately $25,000. If interest is figured at 5 per cent on this value, $1250 would need to be deducted from the farm return of $3368. This would leave $2118 which may be considered to be the return for the labor and management of Mr. B and his son. They have in addition various products and services which the farm furnishes without further cost.

Many farmers would consider this a reasonable return. Mr. B and his son are not satisfied with their present income, however. They have some indebtedness in the farm which they wish to pay off and they would like to build another house for the son and remodel the old house for Mr. B. Therefore they are very anxious to increase their income.

Possible Changes in the Farm Plan

Mr. B, as previously stated, has already decided on his long-time program. His present problem is to determine the most profitable system for the next ten or twelve years. The possibilities that he has considered are milking more cows, keeping more chickens, raising potatoes as a cash crop, or increasing his efficiency with the present organization.

All of the suggestions have some weak points. If he increases the number of cows, it will be necessary to provide more barn room and buy additional roughage. The farm is already producing maximum yields of hay and silage. Building barn room will be expensive.

Keeping more chickens will also mean building another poultry house. Furthermore, the outlook for egg prices in his locality is not very good. So many farmers in the immediate locality have increased their poultry flocks, that a local surplus of eggs has existed for several years. This has tended to keep local prices somewhat below the general level of egg prices.

Raising potatoes as a cash crop would mean initial expense for special machinery. Mr. B has never had much success in securing good yields of potatoes on his farm in the past. Still more important would be the use of several acres of crop land which is needed to produce hay.

Mr. B has spent some time in studying his farm operations to see if his efficiency can be improved enough to dispense with some hired labor. If he were a younger man, it would not be necessary to hire the extra boy. But at

his present age the boy, who does about half a man's work, makes the work easier and leaves him more time for planning. Most jobs on the farm are fairly well planned and efficiently carried out. There seems to be little chance of improving anything enough to do without the boy.

During the 1929 season, Mr. B built a small apple storage, which has greatly increased his efficiency in harvesting apples. The apples can be rushed into the storage just as they come from the trees without sorting, and graded later on when there is more time. This has greatly increased labor efficiency and saved money spent for extra help. Mr. B estimates that there is a chance for some further improvement in later years on these operations. At the best, however, there does not seem to be an opportunity to increase the farm income very much by changes in efficiency.

Suggested Reorganization Plan

After going over the various suggested changes and discarding them one after another, Mr. B finally reconsidered the possibility of increasing the size of the dairy herd. If he could make room for more cows and provide more hay, he could certainly increase his net income. One way to make more barn room would be to dispose of the young stock and depend on buying cows for replacements. This would also release hay and silage which could be fed to the extra cows.

Mr. B hesitated to dispose of his young stock because he had always raised calves and did not like to break up his breeding program. His hesitation disappeared, however, after figuring up his average annual milk production per cow for several years back. He discovered that it was only 5600 pounds of 3.5 per cent milk. He knew from herd improvement association records that several of his neighbors had herds averaging 1000 to 1500 pounds higher. They have surplus stock for sale which he is able to buy at reasonable prices.

Mr. B estimates that disposing of the young stock would permit him to keep 24 milk cows. Figuring on this basis and using the amounts of feed per head and other data from his present organization, Mr. B arrived at the following budget or estimated financial statement for the proposed organization.

TABLE 10.—ESTIMATED FINANCIAL RETURNS FROM PROPOSED ORGANIZATION FARM B.

Receipts		
Whole milk 154,619 lbs. @ $2.60	$4020	
6 old cows @ $50.00	300	
20 calves @ $7.00	140	
Broilers and fowls	293	
Eggs	884	
Apples, 1500 boxes	3022	
Work off the farm	104	
Total Receipts		$8763

Expenses

Hired labor	$ 582	
Grain for cows	1444	
6 new cows bought each year @ $140	840	
Horse grain	147	
Poultry grain	553	
Standing hay 10 tons	25	
Veterinary and medicine	23	
Other cattle expenses	32	
Horseshoeing	14	
Baby chicks	122	
Seeds	32	
Fertilizer and lime	158	
Spray materials	62	
Apple boxes	250	
Repairs	57	
Auto and truck registration, fuel and repairs	257	
Electricity	148	
Telephone	24	
Taxes	192	
Total Expenses		4932
Net Return Above Expenses		$3831
Net Return Over Present Organization		$ 463

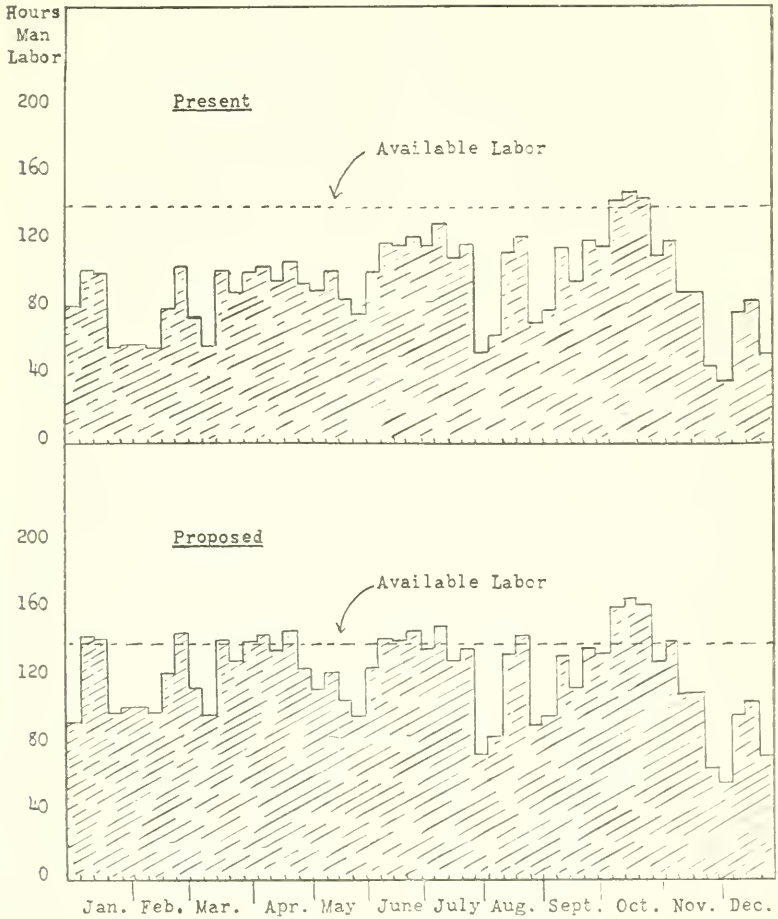
He estimates that the amount of hay and silage released will be nearly enough to feed the extra cows. To make sure, however, he plans to buy five acres of standing hay from a neighboring farm. He can secure this by contract for a period of five years. It will yield about ten tons of fair hay.

The estimate for pounds of milk sold is based on an average production of 6600 pounds, which Mr. B believes he can get with the purchased cows. This production will probably be reached by the time he has replaced about half of the present herd, as he will dispose of the lowest producers first. Mr. B estimates that for several years to come he can purchase high-producing, tuberculin tested cows for $140 per head. If he replaces six cows every year, the expense will be as indicated in the statement. This is probably a conservative estimate.

Receipts and expenses that are not affected by the reorganization are left unchanged. The total receipts under the new plan are $8763 or an increase of about $1500 over the present organization. The total expenses are also increased from $3923 to $4932 or nearly $1000. The net return to the farm business, however, is $463 greater than under the present plan, which is a substantial increase.

The amount of work to be done will be somewhat greater, but the difference will not be more than can be handled easily with the present help. It is estimated that about 40 per cent more time will be spent on the cows, but two-thirds of this amount will be saved from the young stock. Figure 2 shows the actual distribution of man labor for the year under the present organization and the estimated distribution for the proposed organization. Notice that the available labor handles the extra work without difficulty.

Figure 2.—Distribution of Man Labor by Weeks on Farm B for Present and Proposed Organizations.



Changes in expected prices of milk, grain and cows will directly affect the profit from the proposed organization. If milk prices decline without any particular change in other factors, there will be less advantage in the proposed change. Suppose that milk prices dropped fifty cents per hundred pounds. Then the reduction in receipts for the proposed and present organizations would be as follows:

	Reduced Receipts
Proposed: 1546 cwt. @ $.50 lower price	$773
Present: 881 cwt. @ $.50 lower price	441
Difference	$333

There would then be $333 greater reduction in receipts and that much less advantage for the new organization than under present prices. It might be an open question whether it would then be worth while to make the change.

Changes in prices of grain and of cows would also have significant effects on the results. Much depends on the accuracy with which estimates of these factors can be made. Mr. B believes that his estimates are sufficiently conservative to make the change worth while, and plans to shift over to the new system as rapidly as possible.

FARM C—A LARGE DAIRY-FRUIT FARM

A farm with 1000 bearing apple trees and 21 dairy cows is clearly a much larger unit than either of the two preceding farms. The problem of efficient use of labor is of much greater importance on such a farm. Labor may be made more efficient through the use of machinery and equipment, but labor-saving plans are often more important than machinery. Methods of doing work at the time and in the manner that counts for most have been carefully worked out on Farm C.

The operator of Farm C is ably assisted by two grown sons, one of whom is married and has his own house on the farm. Mr. C, himself, has reached the age when many farmers think of retiring, but he retains the controlling voice in the business affairs of the farm and works about half of the total time during the year, putting in full time at periods of peak labor such as apple harvest and less at other seasons. An extra man is hired for about six months, and additional day labor is taken on during apple harvest and occasionally at other times. The successful management of a farm of this type requires a man of more than ordinary capacity and efficiency. Mr. C is fortunate in possessing these characteristics to a marked degree.

The Farm Plan

The details of the farm plan are shown in Tables 11 and 12. These are the actual acreages of crops and numbers of livestock on this farm in 1929. Notice that there is a large non-bearing orchard and a considerable acreage of hay and silage. During the year three acres of hay land were reseeded to alfalfa and four acres of pasture were seeded with a sweet clover and pasture grass mixture. The production and the materials used on each crop are indicated in Table 11.

Ready mixed feeds constitute most of the grain fed to the livestock. The amounts of hay and silage fed are greater than the amount produced during the year. This is because of the unusually dry summer of 1929, which greatly reduced the amount of pasture feed and made it necessary to feed more roughage in the barn during the late summer and early fall. Since good inventories of both hay and silage were carried over from the previous year, the emergency was handled without serious trouble.

TABLE 11.—ACREAGE AND PRODUCTION OF CROPS AND MATERIALS USED ON FARM C.

	Acres	Production	Material Used: Seed	Fertilizer	Ground Limestone	Spray
Apples, 1000 trees	20	2450 bus.		2 tons[4]		...[6]
Apples, non-bearing 700	15					
Peaches, 700	[1]	97 bus.				
Mixed Hay	28	71 tons		½ ton[1]		
Alfalfa	3	9 tons				
Silage Corn	9	97 tons	2½ bus.			
Alfalfa Seeding	3[2]		75 lbs.		8 tons	
Total Crops	75					
Sweet Clover Pasture	4		148 lbs.[3]	2 tons[5]	14 tons	
Pasture	29					
Woods	25					
Farmstead	2					
Total Farm Area	135					

[1] Interplanted with non-bearing apples.
[2] Hay land plowed and seeded after cutting first crop of hay.
[3] Mixture of 75 lbs. sweet clover, 25 lbs. dutch clover and 48 lbs. blue grass.
[4] Nitrate of soda.
[5] Superphosphate.
[6] 435 lbs. lead arsenate, 3 gals. blackleaf 40, 600 lbs. dry lime sulfur, 3 bbls. lime sulfur.

TABLE 12.—POUNDS OF FEED USED BY THE FOLLOWING NUMBERS OF LIVESTOCK ON FARM C.

Feed	Horses 2.3	Cows 20.8	Heifers 9.7	Calves 10.8	Bull 1.0	Poultry 25.5	Totals
Mixed Horse Feed	7,600						7,600
20% Dairy Ration		52,900					52,900
16% Ration		11,923	14,675	3,453	1,349		31,400
Ground Oats		1,500					1,500
Calf Ration				14,200			14,200
Scratch Feed						2,200	2,200
Mash						600	600
Whole Milk				1,040			1,040
Skimmilk Powder				1,140			1,140
Silage		178,253	60,966	6,781			246,000
Hay	16,803	119,790	45,557	18,348	5,503		206,001

TABLE 13.—PRODUCTION, SALE AND USE OF MILK IN 1929—FARM C.

Item	Whole Milk, Pounds
Sold	150,231
Fed	1,040
Home use	5,912
Total	157,183
Production per cow	7,557

The average production per cow for the year is 7557 pounds of milk. This production, while not extraordinary, is very good for a commercial dairy of this size. The cows are pure-bred Holsteins, and the good production is the result of a long-time breeding program combined with careful feeding.

The financial returns for this farm are shown in Table 14. These are the actual receipts and expenses for 1929. The major receipts are about equally divided between the dairy and apples. Sales of cattle add considerably to the dairy receipts. Prices are quite favorable in this year.

TABLE 14.—FINANCIAL RETURNS FROM PRESENT ORGANIZATION—FARM C.

Receipts		
Whole milk 150,231 lbs. @ $2.63	$3951	
6 cows	1012	
2 heifers	225	
10 calves	513	
Eggs, 133 doz. @ $.49	65	
Apples, 2450 boxes @ $1.98	4851	
Peaches, 97 boxes @ $1.75	170	
Cherries	14	
Work off the farm	81	
Farmers' Exchange dividend	50	
Total Receipts		$10932
Expenses		
Hired labor	$ 930	
Grain	2,977	
Shavings	29	
Registration of cattle	54	
Miscellaneous cattle expense	23	
Horseshoeing	9	
Seeds	81	
Fertilizer	182	
Limestone	156	
Sprays	167	
Apple storage	100	
Apple boxes	358	
Building and equipment repairs	219	
Auto, truck, and tractor registration and repairs	235	
Gas, oil, and grease	263	
Telephone	53	
Light and power	174	
Taxes	308	
Miscellaneous expenses	98	
Total Expenses		6416
Net Return Above Expenses		$ 4516

The total farm expenses are $6416. Nearly half of this is expense for purchased grain. Expense for apple boxes is the next largest item on this

list, although automotive expenses and gas and oil when added together amount to more. Expenses for new machinery and for permanent improvements are not included in this statement as they are considered to be capital investments.

The net return of $4516 is the difference between the total receipts and expenses. If an interest allowance of 5 per cent is made on the estimated capital investment of $35,000 a deduction of $1750 would be made, leaving $2766 to be divided between Mr. C and his sons as a return for their labor and management. In addition, of course, the farm furnishes them such items as house rent, fuel, garden produce, milk, and eggs.

Advantages of this Type of Organization

A farm of this type has certain definite advantages as compared with smaller farms similar to A and B. The two principal advantages are economies resulting from the more complete utilization of machinery and equipment and the greater possibility of realizing increased labor efficiency.

The only equipment on Farm C that is not also found on Farm B is a tractor and a larger apple grader. In every other way the two farms are practically identical in equipment. Both have a milking machine, an electric milk cooler, a motor truck, an apple sprayer, wagons, manure spreader and other machinery. With the much larger volume of business on Farm C this means less equipment investment per unit of product. On Farm B the tendency is to continue using some machines after they have depreciated so much as to become relatively inefficient in operation. On Farm C such equipment is replaced much sooner. This situation keeps both machinery and men working at a higher state of efficiency.

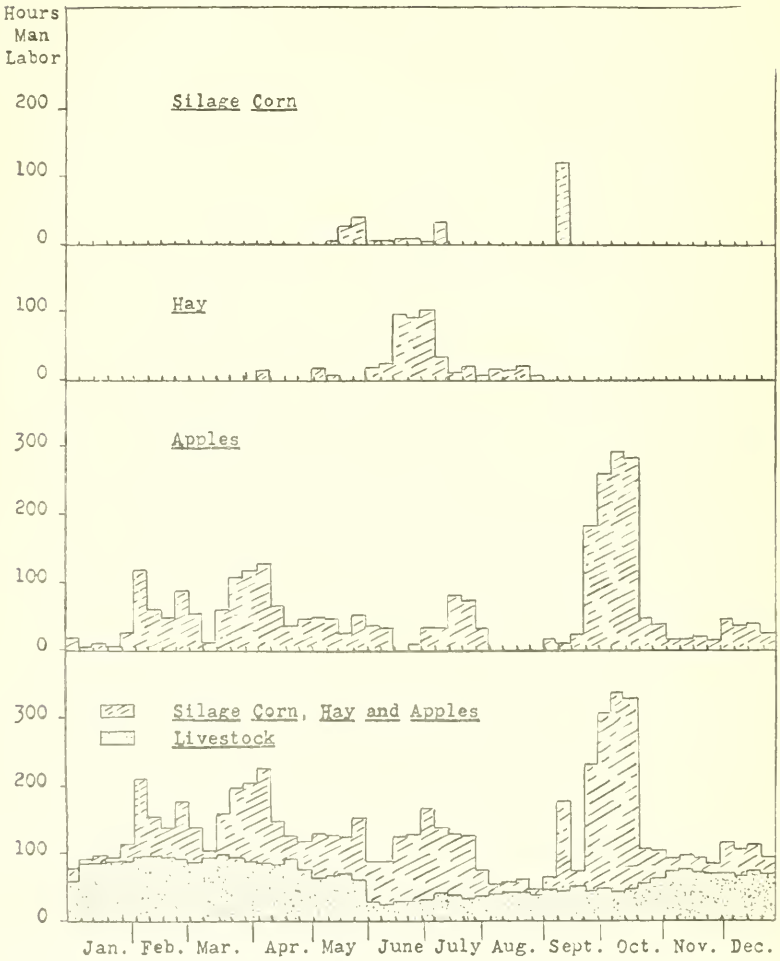
The tractor and the larger apple grader on Farm C are investments which pay their way in labor saving and quality of work. On Farm B they would probably add more to the farm expense than to the receipts. Almost every time the purchase of a new machine is considered it is easier to make it pay for itself on Farm C than on B. Of course, this is most true of the larger types of machinery. In some cases it is possible to secure a smaller machine of lower capacity to fit the needs of the smaller farm.

Planning the Efficient Use of Labor

The outstanding achievement in the operation and management of this farm has been the careful planning of an efficient labor program followed up by efficiency in actually doing specific jobs. Figure 3 shows the distribution of man labor by weeks throughout the year on the crop and livestock enterprises. With the exception of the slack period in August and the high peak of apple picking in September and October, it is a fairly regular distribution. Fall freshening brings the period of least work on cows during the summer when the greatest load of crop work occurs. Notice how the crop and livestock work fit together. Although the adjustment is not perfect, the greatest amount of the livestock labor comes in the winter and the crop work in the summer.

The peak in apple picking is taken care of partly by working longer hours, but chiefly by hiring extra help. The slack period in August is used to good

Figure 3.—Distribution of Man Labor by Weeks on Silage Corn, Hay, Apples and Livestock on Farm C.



advantage in working on buildings, fencing, pasture improvement, and other jobs which have accumulated during the season.

Shifting Crop Labor

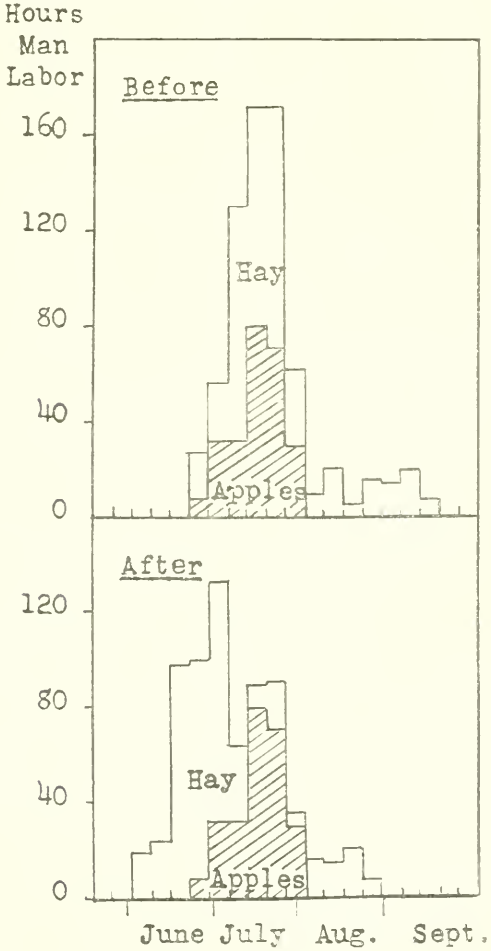
By planning the labor program in advance it has been found possible to make rather extensive shifts in the time of doing some crop operations which are ordinarily considered to be fixed. For example the usual period for making hay in this locality comes at about the same time that apples need thinning. Many farmers neglect thinning in order to put up their hay crop. By

doing this they suffer considerable financial loss on the apples from having a smaller percentage of A grade fruit.

On this farm the practice has been changed to permit earlier haymaking. Some alfalfa is grown and the other mixed hay is simply cut at an earlier stage of maturity. In late seasons this means a small sacrifice in the yield of hay but the extra quality probably more than compensates for this difference. Figure 4 shows the labor distribution on the two jobs of haying and thinning before and after the change of practice. Notice how easily the available labor now handles both operations.

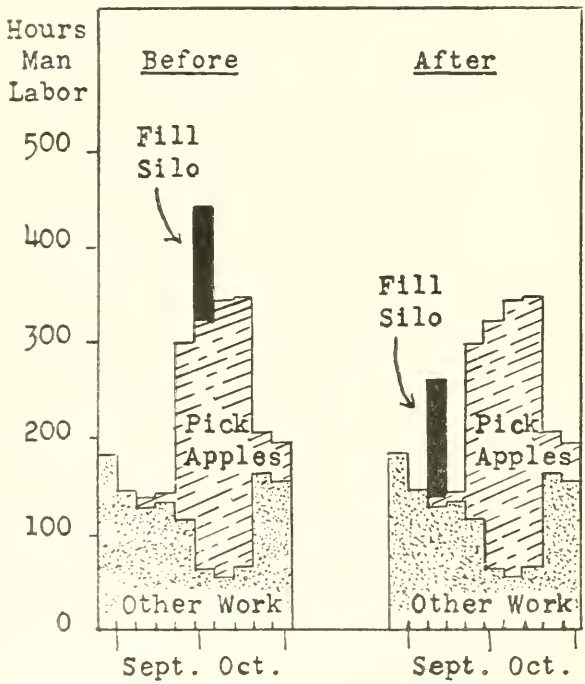
It has also been found possible to shift the date of silo filling to an earlier time than is customary in the locality. Some apple growers have found it necessary to greatly reduce or even drop their silage acreage entirely because

Figure 4.—Distribution of Man Labor on Farm C for Haymaking and Thinning Apples Before and After Shifting the Time of Haymaking.



of the conflict with apple harvest; Mr. C grows an earlier variety of corn and is careful to get it planted on time. He has no difficulty in securing good yields of mature silage corn early enough to avoid the usual labor conflict. Figure 5 shows the labor distribution at this season before and after adopting the practice. The improvement is readily seen.

Figure 5.—Distribution of Man Labor During September and October on Farm C Before and After Shifting the Date of Silo Filling.



Grading, Packing, and Marketing Apples.—Several years ago Mr. C built a fruit storage large enough to hold the bulk of his apple crop and provide room for a mechanical grader. The actual cash construction cost was not great since most of the work was done by the regular farm labor during slack periods. This farm storage makes it possible to extend the marketing season. It spreads the work of grading and packing apples over a longer period so that it can be done by the regular labor supply. The actual harvesting of the apples can be hastened because the fruit can be rushed into the storage house and left in the picking boxes until later when more time is available for sorting. In the 1929 season the work of grading and packing was distributed all through the fall and winter months.

Other apple growers without good storage are compelled either to hire extra labor in order to do a good job of grading in a short time, or else to market the crop with less grading and at a lower price.

Efficiency on Particular Jobs

In addition to planning the seasonal distribution of labor and shifting various operations to different times, Mr. C has carefully studied the efficiency with which particular tasks are performed with a view to reducing both the time and the fatigue. The following discussion covers some of the more significant of his results along this line.

Reducing Livestock Labor.—By referring to Figure 3 an idea of the relative amount of the labor required by the livestock may be gained. The greater part of this consists of routine daily chores which are much the same throughout the year. Although Mr. C's barn is rather old, with only a fair arrangement, he has been able to plan a schedule for his chores which permits him to care for the cows in about two-thirds the time used by many dairymen. He spends approximately 100 hours per cow annually as compared with a common standard of about 150 hours.

He has built a grain chute which brings the grain from an upstairs grain room down close to the cows, and a hay chute which makes the feeding of the hay much easier. In feeding silage, the silage cart is backed up to the silo door so that when the silage is thrown out it loads the cart. With the cart it takes about 24 minutes daily to feed silage twice, while one of the neighboring dairymen takes about 36 minutes daily in feeding silage to the same number of head with a bushel basket. When the milk room was built, it was placed at one end of the barn, as near to the milk cows as possible and was planned for convenience in handling the milk and washing the milk utensils.

In remodelling the barn a few years ago Mr. C arranged to pipe water to a water trough inside the horse stable. It takes only about half as long to care for the horses now as it did formerly when they had to be led outside the barn or water carried in to them. Now he simply turns the horses loose inside the stable and while they are drinking puts in the hay and bedding and cleans out the stable. The whole operation takes only six or seven minutes each time.

Efficiency in Haymaking and Silo Filling.—The following table tells its own story concerning Mr. C's efficiency in organizing haying and silo-filling labor. The only special labor-saving machinery is a power hay hoist at the barn for use in unloading. Only the ordinary haying tools—mower, dump rake, and hand forks—were used in the field.

TABLE 15.—COMPARISON OF HAY AND SILO-FILLING LABOR ON FARM C AND OTHER MASSACHUSETTS FARMS.

	Farm C	Other Mass. Farms*
Hay		
Man hours per acre	13.8	16.7
Man hours per ton	5.3	8.4
Silage		
Man hours per acre	13.3	30.5
Man hours per ton	1.2	2.9

* Records in 1924 from 54 Massachusetts farms for hay and 32 farms for silage, using about the same kind of equipment as on Farm C.

In silo filling, the corn is cut by hand and handled loose. The efficiency in the amount of labor used both in haying and in silo filling is accomplished by carefully planning the work to avoid waste effort and lost motion all along the line. The use of low rack wagons and a systematic method of loading saves much of the time on both of these crops.

Packing and Grading Apples.—Mr. C grades and packs most of his apples in standard bushel boxes. Paper wraps are used for part of the crop. His large mechanical grader not only saves labor but makes it possible to do a better job than would otherwise be the case. On one occasion in 1929 a crew of five men graded, wrapped, packed, and boxed 600 boxes of A grade Baldwins and 300 boxes of B grade in 135 man hours. This time was spread out over a week and mixed in with some other work so that full efficiency was not attained. Probably this machine about doubles the speed of packing for the same grade of work. Other apple growers may grade just as rapidly by hand but they do not put up the same quality of pack.

Mr. C has carefully studied the whole process of packing apples, for the purpose of improving methods. Some of his practices are:

1. The grader is set up for convenience in filling with apples, and with regard to the natural and artificial lighting.

2. The box stand, which holds the box into which each man packs apples, is tilted and adjusted for elevation to suit the height and arm length of each individual. The adjustment is readily changed to fit different workers. This item is particularly important in reducing fatigue.

3. The process of wrapping each apple has been reduced to a few simple motions and standardized for each person. This increases packing speed and reduces fatigue.

4. In nailing box tops, the box is held in a homemade clamp or press, operated by a foot lever. The press holds the top of the box tightly in place and the nailer has both hands free. The device is simpler and more effective than many commercial devices for this purpose.

5. Empty boxes are conveniently placed within reach and the packed boxes are stacked with reference to loading out.

All of these factors tend both to speed up the rate of packing and to reduce the fatigue. At the end of the day the men are much less tired than they would be under the usual working conditions.

Summary of Labor Efficiency

Without going into more detail, the preceding discussion shows something of the methods followed by Mr. C in planning the seasonal distribution of labor and in increasing the efficiency with which daily tasks and special jobs are done. The net result has been the accomplishment of a larger volume of business per man than otherwise would have been the case.

Some of these economies can be realized equally well on a smaller farm, while others which require more investment in machinery are less easily attained. Generally speaking, labor efficiency affects farm profits more on the larger farm because it can more frequently be translated into dollars-and-cents saving of hired labor.

Suggested Changes in Organization and Operation of Farm C

Most of the major adjustments possible in the long-time organization of this farm have already been made. There is now more opportunity for improvement in certain minor phases of the organization and operation. The following three problems are probably most significant on this farm at the present time:

1. Improvement of hay and pasture land.
2. Use of more equipment in haymaking and silo filling.
3. Labor organization at apple-picking time.

Hay and Pasture Improvement

Any method of improvement of the hay and pasture land is worth while which adds more to the net farm income than it takes away through direct cost or interference with other phases of the farm business. This farm already produces excellent yields of good quality hay. In most seasons there is sufficient roughage to supply the needs of the livestock. In some years like 1929, however, there is a shortage. Mr. C has demonstrated on a small scale that he can grow alfalfa successfully without difficulty for a reasonable cash outlay. Now is the time to expand the acreage of alfalfa. This will give him a greater production of hay. The higher quality will also make possible some reduction in the grain ration fed the dairy cows. A further advantage will be an improvement in labor distribution on hay. The second cutting of alfalfa will cause a larger proportion of the haymaking to come in late summer when there is less conflicting demand for labor. The first cutting will come ahead of apple thinning and work out as well as the present distribution.

There is now plenty of June pasture. There would be no advantage in improving pasture production at this period. If more early feed or midsummer grass could be obtained without excessive cost it might prove profitable through saving grain or hay. Early pasture would also help to reduce barn chores during the rush of spring work on apples and silage corn.

Mr. C is also experimenting on a small scale with sweet clover pasture. The dry weather in 1929 affected his results, but he expects to do better in ordinary seasons. He is not so certain of the value of fertilizing to secure early spring pasture, but plans to try it out on a small area to determine how successful it will be under his conditions.

Use of Machinery for Haymaking and Silo Filling

The labor of haymaking could be considerably reduced by the use of a hay loader and side delivery rake. Time records show that three men can load hay about 50 per cent more rapidly with a hay loader than by hand. They can also do it with less fatigue. After allowing for the hauling distance, the size and shape of fields and other factors, it is estimated that all the hay on this farm could be put in the barn with about 25 per cent less man labor by making this change. The initial extra investment would be about $300. If the saving in time did not warrant this expense, the improvement in quality of the hay, due to more rapid curing in the field as well as quicker removal to the barn, might make it profitable.

Silo-filling labor, although very efficient for the methods now in use, could be reduced still further by using a corn binder. Judging from trials under actual farm conditions in Connecticut in 1929, it should be possible to reduce the labor of filling silo to a total of about 90 hours for the 9 acres instead of 120 hours as at present. Table 16 shows the comparison between silo filling labor on this farm under present conditions and on the two Connecticut farms.

TABLE 16.—COMPARISON OF TIME USED IN FILLING SILO ON FARM C AND ON TWO CONNECTICUT FARMS IN 1929.

	Farm C	Two Conn. Farms*
Man hours per acre	13.33	9.90
Man hours per ton	1.25	0.97

* Labor efficiency in producing corn silage.—Economic Digest, October 1929, Connecticut Agricultural College, Storrs, Conn.

On the two Connecticut farms corn binders were used and the work was planned to take advantage of the bundles. These could be loaded and unloaded much more quickly and easily than loose corn.

Although the work is now planned to get silo filling completed before apple harvest, the additional time saved by the corn binder might be well employed in preparation for this peak labor load. The actual decision as to the purchase of any of these machines should be based not only upon the value of alternative uses for the time saved, but also upon whatever value may be placed on the reduction of fatigue. There is no doubt that the work would be much less irksome and disagreeable with the machinery.

Labor Organization at Apple Picking Time

More extra hired labor is taken on at apple harvest than at any other time. This is the highest peak load of labor in the entire year and lasts about a month. It would be worth while to study the entire organization of work for this period to see if economies cannot be realized. This is especially important because the orchard is not yet in full bearing and the labor will increase considerably for some years to come. Every hour of time saved at this season means so much less expense for hired help.

CONCLUSION

General recommendations for adjusting certain lines of agricultural production or adopting certain farm practices are sometimes made. Such recommendations frequently overlook the wide differences in farm organization and in farmers' capacity and efficiency that are always found even in the same locality. Some farmers may be so situated that they may profitably follow a plan directly contrary to that which is best for others.

As opposed to accepting such blanket recommendations at their face value, the analysis of the three farms in this study leads to the conclusion that farm

readjustments should be planned only after a careful study of the particular situation. This is the best method for the individual farmer to follow in making his own farm plans. It is the way in which many successful farmers plan their farming systems. New types of machinery, new methods of production, changes in prices of farm products and other factors are all interpreted in the light of their own individual farm organizations.

This study presents an analysis of some common types of problems for which solutions have been found to fit in these particular cases. Exactly the same adjustments might not fit other farms. They may, however, serve as valuable suggestions to other farmers in like situations.

A further conclusion to be drawn from this and similar studies is that some method of budgeting or careful estimating of future receipts and expenses is an essential step before making any farm adjustment. Suggested changes may increase receipts in one direction and at the same time decrease the income from other sources. The only safe way of balancing the various changes is to make careful estimates of each item affected by the proposed adjustment. Records of farm receipts and expenses, crop yields, livestock production, and amounts of materials used in previous years increase the accuracy with which these estimates can be made.

4M-6-'31. No. 2727.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 276 June, 1931

Increasing Soil Acidity as a Means of Controlling Black Root-Rot of Tobacco

By William L. Doran

Soils with a pH value of about 5.9 or higher are favorable to the growth of the fungus which causes black root-rot and are therefore unsafe for tobacco. The primary object of the work here described was to study means of lowering the pH value of soil infested with Thielavia basicola, and thereby decreasing the loss caused by black root-rot of tobacco.

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INCREASING SOIL ACIDITY AS A MEANS OF CONTROLLING BLACK ROOT-ROT OF TOBACCO

By William L. Doran, Research Professor of Botany

INTRODUCTION

It has been established by several investigators (5, 24, 13)[1] and it is now well known that a soil made less acid, as by the application of lime, becomes favorable to increased infestation by *Thielavia basicola* (Berk. and Br.) Zopf and to black root-rot of tobacco caused by this fungus. Soils with a pH value of about 5.9 or higher, depending somewhat on soil temperature (14), are therefore unsafe for tobacco, and so they remain until the hydrogen-ion concentration of the soil is sufficiently increased or until the infestation of the soil by the fungus, because of this or some other cause, subsides.

Strains of tobacco resistant to black root-rot may, however, be grown in such soil, and so far as resistant strains, now or later available, are satisfactory to growers and to manufacturers, this is the solution of the problem.

It has sometimes been considered necessary, when such strains were lacking, to use infested soil for some other crop than tobacco until the infestation subsided; but, in the case of a soil otherwise good for tobacco, this is an unsatisfactory solution, for, according to Johnson and Milton (20), it may require as many as ten years for Thielavia to die out in the soil even in the absence of tobacco.

Basic constituents are in the course of years removed from the soil by leaching and in the crops, but the return of an over-limed soil to a sufficiently acid condition to permit good growth of tobacco may be a very slow process, as is illustrated subsequently in the present paper.

The primary object of the work here described was to study means of more quickly lowering the pH value of soil infested with *Thielavia basicola* and thereby decreasing the loss caused by black root-rot of tobacco. It is well known that the pH value of a soil may be lowered by the application of sulfur or acids, and one of the principal objects was to determine to what extent this method is effective and practical in protecting tobacco against black root-rot.

The possibility of using sulfur or an acid for this purpose has already received some attention. In the experiments of Briggs (9), the application of hydrochloric acid to a soil infested with *Thielavia basicola* resulted in a marked reduction in the severity of black root-rot and a small increase in the growth of tobacco. Chapman (12) found that applications of sulfuric acid or sulfur resulted in less black root-rot of tobacco and no interference with growth of the plants. Routt (27) found sulfuric acid beneficial to tobacco (in some cases) when applied to soil infested with Thielavia. According to Anderson and Swanback (7), about 500 pounds of sulfur per acre caused an optimum increase in soil acidity, but they did not record the effect of this treatment on black root-rot or on the yield or quality of tobacco.

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[1] Reference is made by number to "Literature Cited," p. 138.

PRELIMINARY EXPERIMENTS

A brief summary of the results of some of these preliminary experiments has already been published (13).

The soil used, except as otherwise indicated, is an ice-deposited stony loam, heavily infested with *Thielavia basicola*. To determine the quantity of each acid necessary to cause the desired lowering of the pH value of the soil, a known number of cubic centimeters of a normal acid was applied in preliminary experiments to each 100 grams of air-dry soil, together with enough water to bring the soil up to 60 per cent of its water-holding capacity. The pH values of the soil were determined at various intervals of time thereafter.[2]

With Sulfuric and Nitric Acids

Sulfuric and nitric acids were about equally effective in increasing the hydrogen-ion concentration of this soil and in reducing the intensity of infection of tobacco by Thielavia; but nitric acid was so toxic to tobacco plants that it was not used in subsequent field experiments.

The growth of tobacco could be correlated with pH value of acidified soil only as each acid was considered separately. For example, an application of nitric acid by which the pH value of the soil was lowered to 5.5 (from 6.0) prevented practically all growth of tobacco, while an application of sulfuric acid by which the pH value of the soil was lowered to 4.6 (from 6.0) permitted good growth of tobacco. The hydrogen-ion concentration of the soil is not the only factor involved, and as Carr and Havercamp (11) have pointed out, the toxicity to plants of an acid applied to soil is possibly attributable to easily soluble salts (as of iron and aluminum) which the acids form in the soil. Be that as it may, it appears that the optimum pH value of soil for the growth of tobacco (and presumably other plants) is not fixed but depends partly on the means by which the soil reaction is adjusted.

With Orthophosphoric Acid

A greater increase in growth of tobacco resulted from the application of orthophosphoric acid than from either sulfuric or nitric acid; although orthophosphoric acid had much less effect in lowering the pH value of the soil than either of the others, and did not at all reduce the intensity of infection by Thielavia. Whenever orthophosphoric acid was applied to soil infested with this fungus, black root-rot was severe or rather more severe, although the pH value of the soil was thus lowered as much as to 5.0; but when orthophosphoric acid was applied to soil not limed and not heavily infested with Thielavia, no increase in black root-rot resulted.

In one series of pot experiments, orthophosphoric acid, in the amounts named in Table 1, was applied to limed soil infested with Thielavia, and tobacco plants were grown in soil so treated. The initial pH value of this soil was 5.9. The application of orthophosphoric acid lowered the pH value of

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[2] In the preliminary experiments and in the field experiments in 1926 and 1927, the pH values of the soil were determined colorimetrically by a method previously described (3). The soil pH values in the field in 1928, 1929, and 1930 were determined electrometrically.

TABLE 1.—EFFECTS OF ORTHOPHOSPHORIC ACID ON pH VALUES OF SOIL AND ON GROWTH AND BLACK ROOT-ROT OF TOBACCO IN LIMED SOIL.

Orthophosphoric acid per 100 grams dry soil c.c. of N/1 acid	pH values of soil	Black root-rot	Dry weights of plants Grams
None	5.9	Moderate to severe	8.54
15	5.0	Severe	12.40
20	5.0	Severe	22.04
25	5.0	Severe	17.54

the soil from 5.9 to 5.0, but black root-rot of tobacco was nevertheless severe—rather more severe at pH 5.0 with orthophosphoric acid than at pH 5.9 without this acid. The degrees of infection may be seen by reference to Figure 1. Plants were larger, however, with orthophosphoric acid than without it.

It is evident from this that other factors than or in addition to the hydrogen-ion concentration of the soil are involved. This soil with its pH value lowered by orthophosphoric acid far below the usually accepted danger point for black root-rot was no less, in fact it was little more favorable to infection of tobacco by Thielavia than the same soil with the initial pH value of 5.9 but without treatment with orthophosphoric acid.

Some phosphorus is of course necessary for the growth of tobacco, although according to Anderson and his co-workers (4) tobacco on old tobacco land in Connecticut may be grown without any carrier of phosphorus in the fertilizer mixture, since large quantities have accumulated in such soils.

The work here described was confined to pot experiments, but so far as these results are indicative, they suggest applying no more phosphorus than is necessary for the best growth of tobacco when one object is to hasten the dying-out of Thielavia in over-limed and infested soil.

As described in a later part of this paper, however, there was no increase in black root-rot when sulfuric acid and orthophosphoric acid were used together in the field.

With Aluminum Sulfate and Sulfur

It is possible that certain soluble toxic substances, for instance salts of aluminum, in addition to (or instead of) hydrogen-ion concentration, inhibit the growth of *Thielavia basicola* in acid soil, and that orthophosphoric acid as well as lime inactivates these toxic substances with consequent benefit to the fungus. This is in line with the explanation by Carr and Havercamp (*loc. cit.*) of the beneficial effect of phosphoric acid on growth of plants, i. e., phosphoric acid forms less available and less toxic compounds with iron and aluminum in the soil.

Sulfur, sulfuric acid, and aluminum sulfate ($Al_2(SO_4)_3 \cdot 18H_2O$), separately or together, were added to soil infested with *Thielavia basicola*, and tobacco plants were grown in this soil (in 2-gallon crocks). The effects of each treatment on soil pH value, dry weight of plants, and black root-rot are recorded in Table 2.

The pH value of the soil was lowered by all treatments, but more by aluminum sulfate with sulfuric acid or sulfur than by either of these chemicals alone. All of the acidification treatments reduced the severity of black root-rot, although none of them eliminated it.

TABLE 2.—EFFECTS OF ALUMINUM SULFATE ALONE AND WITH SULFURIC ACID OR SULFUR ON pH VALUES OF SOIL AND ON GROWTH AND BLACK ROOT-ROT OF TOBACCO IN LIMED SOIL.

Soil treatment (Grams per pot)	pH values of soil After 2 weeks	After 11 weeks	After 18 weeks	Dry weights per plant* Grams	Relative numbers	Black root-rot
Check	6.2	6.0	5.9	25.41	100	Severe
Sulfuric acid 5.9	5.2	5.1	5.2	32.63	128	Mild to moderate
Sulfur 1.9	5.5	5.3	5.3	31.43	124	Mild to moderate
Aluminum sulfate 4.4, Sulfuric acid 5.9	5.0	5.0	5.1	22.89	90	Mild to moderate
Aluminum sulfate 4.4, Sulfur 1.9	5.3	5.1	5.2	36.24	142	Mild to moderate
Aluminum sulfate 6.5, Sulfuric acid 5.9	4.9	4.9	5.3	26.41	104	Mild to moderate
Aluminum sulfate 6.5, Sulfur 1.9	5.2	4.8	4.8	27.02	106	Mild to moderate
Aluminum sulfate 4.4	5.5	5.5	5.7	26.39	104	Mild to moderate
Aluminum sulfate 6.5	5.7	5.2	5.2	20.91	82	Mild to moderate

* Means for duplicate treatments.

Aluminum sulfate used alone resulted in no significant increase in dry weight of plants; in fact, the heavier application interfered with growth. Dry weights of plants were increased 28 per cent by sulfuric acid and 24 per cent by sulfur; but this same application of sulfur when used with aluminum sulfate resulted in an increase in dry weights of plants of 42 per cent.

It appears from this that aluminum sulfate added to the soil had an unfavorable effect on *Thielavia basicola,* and that the effect on the disease which this fungus causes was greater when the soil acidity was further increased as by the use of sulfur.

With Sulfuric and Orthophosphoric Acids Used Together

The pH value of soil was lowered as much by sulfuric or nitric acid alone as by the use of either of them with orthophosphoric acid; but tobacco grew better when orthophosphoric acid was used with sulfuric or nitric acids than when either of the last two named acids was used alone. In the preliminary experiments there was rather less black root-rot when sulfuric or nitric acid was used alone than when either of them was used with orthophosphoric acid, but this effect of the latter was more than offset by the improved growth of the plants.

On the basis of these experiments it was decided to use (together) sulfuric acid, 1800 pounds per acre, and orthophosphoric acid (80 per cent), 440 pounds per acre, in the field experiments subsequently described. The quantity of acidifying chemical necessary to apply to a soil in the field to cause a

desired lowering of pH value of the soil and the quantity which may be applied with safety to plants, may vary with the soil and cannot be predicted with any degree of exactness except by preliminary experiments with the particular soil.

In one series of these preliminary experiments, the same acid treatments were applied to two soils. One of these, a water-deposited fine silt loam high in organic matter, was well buffered and resisted change in its pH value. The other soil, an ice-deposited stony loam, was not as well buffered and its pH value was consequently more readily lowered by the same application of an acid. As has been pointed out by others (28, 21) the effect of an application of acid on the pH value of soil and on plants and fungi in that soil depends on the type of soil. Acids in the the same quantities were somewhat more toxic to plants in the well-buffered soil.

FIELD EXPERIMENTS

Methods and Plan of Work

These experiments (except as otherwise indicated) were carried on in a field the history and plot treatments of which up to 1925 have already been described (5). Certain plots had received applications of lime to a total of 5 tons per acre, the last of which was applied in 1923. In these limed plots pH values were high enough to favor *Thielavia basicola*, black root-rot was severe, and yields of tobacco were consequently low. Tobacco was grown on all plots from 1922 to 1925 inclusive. Soil treatments and crops of each plot from 1926 to 1929 inclusive were as recorded in Table 9.

The fertilizers used each year and the amounts of each material are shown in Table 10. These were applied immediately before tobacco plants were set.

In 1926 sulfur (inoculated), 200 or 400 pounds per acre, or sulfuric acid, 1800 pounds, together with orthophosphoric acid (80 per cent), 440 pounds per acre, were applied to the plots so indicated in Table 9. This was done one month before plants were set. The acids and the sulfur were harrowed into the soil immediately after their application. In 1927 sulfur and the acids were applied again and in the same amounts to the plots named in Table 9, two months before the tobacco plants were set. Some plots received these treatments, therefore, in one year only, and others received them in two successive years. No acidifying chemicals were applied after 1927.

In order to determine how tobacco compared with some other crops in removing lime from the soil and in lowering the pH value of soil, timothy was planted in the fall of 1925 and alfalfa and alsike clover in the spring of 1926 on the plots indicated in Table 9. The hay crops were grown on these plots in 1926 and 1927. In 1928 half of each hay plot was again set with tobacco, and in 1929 and 1930 the other half of each hay plot was again used for tobacco. There were thus available for comparison plots on which tobacco was grown every year and plots on which tobacco was grown following two or three years of each of these other crops—alfalfa, alsike clover, or timothy.

Each year the tobacco from each of the several plots was cut, cured, stripped, and sorted separately. The fire-holding capacity or duration of burn of samples of leaf from each plot was determined in strip tests.[3] The quantities of calcium and magnesium oxides removed in each crop (including stalks

[3] The burn of the leaves was initiated by means of an electrical resistance coil. Five leaves from each grade were used and four tests were made on each leaf.

of tobacco) from each plot were determined.[4] Roots of tobacco plants were examined for black root-rot and brown root-rot at the time the tobacco was cut.

The pH value of the soil, the yields per acre of cured leaf, the results of the sorting, burn tests, and root examinations are recorded for each plot and each year so far as they are available, in Tables 11-15 in the appendix.

Effects of Lime

On pH values of Soil and on Yields of Tobacco.

The pH values of the soil in limed plots 12 and 24 may be compared with the pH values of soil in unlimed plots 5, 17, 6, and 18 by reference to Tables 11-15, for the years 1926, 1927, 1928, 1929, and 1930. None of these plots received sulfur or acids.

The pH value of limed soil did not change more than 0.2 from 1926 to 1930 inclusive, and that change was from about 5.9 to 6.1, or not in the direction of increased acidity. Soil pH values in limed plots were still favorable to *Thielavia basicola* in 1930, seven years after the application of lime. The soil in plots not limed had meanwhile become increasingly acid, the pH values changing from about 5.4 in 1926 to about 5.0 in 1930.

In Table 3 the yields of tobacco on plots not limed are compared with the yields on the limed plots, and the losses in yield on limed plots, expressed as percentages of yields on plots not limed, are recorded. Tobacco was grown every year on all of these plots and to none of them were acidifying chemicals applied.

TABLE 3.—EFFECTS OF LIME (APPLIED LAST IN 1923) ON YIELDS OF TOBACCO FROM 1925 TO 1930, INCLUSIVE.

Year	Yields per acre		Loss in yield on limed plots
	Unlimed plots	Limed plots	
	Pounds	*Pounds*	*Per cent*
1924	1548	1395	10
1925	1230	673	45
1926	1648	935	43
1927	1536	987	35
1928	789	920	None
1929	1519	1170	23
1930	1924	1438	25

* Means for duplicate plots.

The loss caused directly by black root-rot (as evidenced by root examinations) on plots last limed in 1923, reached its maximum (45 or 43 per cent) in 1925 and 1926, and was considerably less in 1927.

In 1928 the total precipitation in June, July, and August was 74 per cent more than the normal for this period. As Chapman (12) has pointed out, excessive summer rainfall in Massachusetts is always followed by a reduction in the yield of tobacco. Furthermore, the soil in this field is not very well

[4] By Philip H. Smith and Henri D. Haskins of Massachusetts Agricultural Experiment Station.

drained, and under these conditions of excessive rainfall tobacco grew so poorly on all plots that the effects of the several soil treatments on growth were largely obscured. Yields on all plots, limed or not limed, were the lowest they had ever been, and topography of the field had for the first and only time some effect on the growth of tobacco; in thirteen out of seventeen pairs of duplicate plot treatments, the plots in the lower half of the field yielded less than the plots in the higher half of the field.

Limed plots yielded 23 per cent less in 1929 and 25 per cent less in 1930 than did plots not limed. Thus, seven years after liming, the soil was still sufficiently favorable to *Thielavia basicola*, as evidenced by yields (and infection of roots), to prevent the profitable growing of tobacco on limed plots. But the loss caused by lime, applied in 1923, decreased from 45 per cent in 1925 to 23 per cent in 1929.

On Quality and Burn of Tobacco

The index of quality used for purposes of comparison is the percentage of leaf of the grades lights, mediums, and seconds in the tobacco from each plot.

In general, lower yields on limed plots were associated with poorer quality. In 1926 (Table 11) 48 per cent (mean for duplicate plots 5 and 17) of the tobacco from plots without lime was mediums and seconds, and only 26 per cent (mean for duplicate plots 12 and 24) of the tobacco from limed plots was so classed. Again in 1927 (Table 12), there was a higher percentage of mediums and seconds from plots not limed than from limed plots. But in 1928, 1929, and 1930 (Tables 13-15), with smaller differences in yield between limed and unlimed plots than in earlier years, the quality of tobacco on limed plots was not definitely inferior to the quality of tobacco on plots not limed.

In addition to the crops of the years discussed in this paper, the burn of the tobacco of the crops of 1924 and 1925 (described in an earlier report (5) from plots with and without lime was tested.[5]

In 1924, the first year after the last application of lime, the fire-holding capacity of both darks and seconds from limed plots was considerably better than that of corresponding leaves from plots not limed, as may be seen by reference to Table 4.

TABLE 4.—FIRE-HOLDING CAPACITY OF TOBACCO, CROP OF 1924.

Grade of leaf	Soil treatment	Percentage of tests in which the burn was: Good *Per cent*	Fair *Per cent*	Poor *Per cent*
Seconds	Limed plots	56	37	7
	Plots not limed	25	42	33
Darks	Limed plots	30	50	20
	Plots not limed	0	54	46

In five out of six comparisons made in the crop of 1925, the fire-holding capacity of the seconds was better without lime than with it. In six out of nine comparisons of the darks in this crop, the fire-holding capacity was as

[5] The burn of the crop of 1924 was tested by Walter Edwards and that of 1925 was tested by J. P. Jones, formerly Research Professor of Agronomy in Massachusetts Agricultural Experiment Station

good without lime as with lime: but in the other three comparisons, burn was of longer duration with lime than without it. The differences were not great, and the only conclusion is that the burn of the tobacco of 1925 was not consistently better or worse in limed plots than in plots not limed.

From Table 11 it is seen that the burn of the crop of 1926 was somewhat better with lime (Plots 12 and 24) than without it (Plots 5 and 17). The increases in fire-holding capacity on limed plots were 45 per cent in the mediums, 24 per cent in the seconds, and 61 per cent in the darks.

In 1927, however, liming did not consistently improve the burn. Lime was associated with a better burn of the seconds on one plot (Plot 24) but not on its duplicate (Plot 12), and in three out of four possible comparisons lime did not improve the burn of the darks. (Table 12.)

The fire-holding capacity of the crop of 1928, the year of the rainiest growing season, was very good on the whole, and the burn of both darks and seconds from plots not limed was as good as or better than the burn of the corresponding leaves from limed plots. (Table 13.)

In 1929 seconds from limed plots 12 and 24 held fire slightly longer (mean of 29 seconds) than did leaves of this grade from plots 5, 6, 17, and 18, not limed, (mean of 26 seconds); but darks from the limed plots did not hold fire quite as long (mean of 16 seconds) as did darks from the unlimed plots (mean of 18 seconds). The differences are small and inconsistent and show only that liming was without significant effect on burn in 1929. (Table 14.)

In four out of these six years lime in the amounts applied to this soil did not improve burn of the leaf: that is, it did not increase the fire-holding capacity as determined by strip tests. In only two years, 1924 and 1926, did lime improve burn.

These results are in general agreement with those presented in the literature on this subject. In the experiments of Ames and Boltz (1), the application of lime to the soil shortened the time of burning of tobacco. According to Haley (18), lime does not improve the combustion of cigar leaf to any extent and if applied in large quantities it may injure burn. Garner (16) has reported that lime does not much affect the fire-holding capacity of tobacco. Lime reduced the fire-holding capacity of tobacco in strip tests, but not in cigar tests, in Connecticut (6).

Considering only unlimed plots 5 and 17, the best burn of these four years was in the rainiest season and the poorest burn was in the dryest season. The differences were greater than those associated with lime or no-lime treatments of the soil.

Year	Rainfall (June, July, Aug.)	Length of burn in seconds (Unlimed Plots 5 and 17)	
		Darks	Seconds
1926	9.25	6	9
1927	11.78	13	13
1928	21.60	41	25
1929	12.11	13	20

Effects of Tobacco, Alfalfa, Timothy, and Alsike Clover

On Soil Reaction and Removal of Lime in the Crops

The number of pounds of calcium and magnesium oxides removed in each of these crops from each plot in 1926, 1927, and 1928 is recorded in Table 5.

TABLE 5.—CALCIUM AND MAGNESIUM OXIDES REMOVED FROM SOIL IN CROPS, 1926, 1927, AND 1928.

Plot No.	Crop	CaO and MgO Pounds per acre	Plot No.	Crop	CaO and MgO Pounds per acre
1b	Alsike clover	113.45	13b	Alsike clover	127.75
2a	Timothy	78.34	14a	Timothy	81.03
3a	Tobacco	339.05	15a	Tobacco	334.58
3b	Tobacco	312.09	15b	Tobacco	336.08
4a	Tobacco	277.56	16a	Tobacco	324.87
4b	Tobacco	324.17	16b	Tobacco	322.94
5	Tobacco	306.49	17	Tobacco	333.78
6	Tobacco	277.71	18	Tobacco	297.20
7b	Alfalfa	189.73	19b	Alfalfa	209.63
8a	Timothy	82.91	20a	Timothy	101.69
9a	Tobacco	214.18	21a	Tobacco	267.87
9b	Tobacco	201.91	21b	Tobacco	264.07
10a	Tobacco	261.43	22a	Tobacco	293.78
10b	Tobacco	255.97	22b	Tobacco	303.61
11a	Tobacco	312.28	23a	Tobacco	357.88
11b	Tobacco	292.77	23b	Tobacco	310.10
12	Tobacco	182.53	24	Tobacco	209.89

From limed plots, in the absence of acidifying treatments, alfalfa removed as much calcium and magnesium oxides as did tobacco (but no more), and timothy did not remove half as much as did tobacco. Tobacco was similarly more effective than alsike clover on plots not limed.

Much more of the calcium and magnesium oxides was removed by tobacco on limed plots acidified with sulfur or with sulfuric and orthophosphoric acids than by tobacco, alfalfa, or timothy on limed plots not acidified.

The effects of tobacco, alfalfa, and timothy on the pH values of soil in limed plots in the years 1926 to 1930, inclusive, may be compared by reference to Tables 11-15. The pH values of the soil in all of these limed plots were about 6.0 or 6.1 in 1930, and in no case were they lower in 1929 and 1930 than in 1926; in fact, they were all somewhat higher in the last two years.

The substitution of alfalfa or timothy for tobacco for two or three years did not result in soil reactions any less favorable to *Thielavia basicola*. If, or when, these crops have any effect on black root-rot of tobacco which may follow them in a rotation system, this effect is apparently exerted through some other factor than soil reaction.

Alfalfa and Black Root-Rot

Black root-rot caused by *Thielavia basicola* has been reported (2, 19) as occurring on several species of legumes, including alfalfa. There is an opinion (12, 17), therefore, that legumes should not be grown preceding tobacco in a cropping system. According to Major (22) and Burkholder (10), alfalfa is susceptible to infection by *Thielavia basicola;* but in experiments by Johnson (19) the susceptibility of alfalfa to this fungus was classed as low (compared with that of other hosts). Thielavia has been reported (2) as occurring on alfalfa in only three states, although the roots of alfalfa have presumably been examined by plant pathologists in many more.

The results of the observations now to be described indicate that alfalfa is not sufficiently susceptible to black root-rot caused by Thielavia to preclude, for that reason, the growth of alfalfa in rotation with or preceding tobacco.

The soil of the limed plots on which alfalfa was grown following four years of tobacco was very completely infested with Thielavia, as evidenced by the severe infection of tobacco in the preceding and the succeeding years. The relative susceptibility or resistance of alfalfa to infection by this fungus was, therefore, put to a real test.

Roots of alfalfa were examined each year. The roots showed a kind of pitting very similar in appearance to an injury of underterminded cause which has been described by other investigators (31, 29); but no infection by *Thielavia basicola* was found, although soil conditions and the abundant presence of the fungus were most favorable to it.

As far as black root-rot is concerned, therefore, there seems to be no reason why alfalfa cannot be grown in a rotation preceding tobacco.

On Black Root-Rot, Brown Root-Rot, and Yields of Tobacco

In 1928, 1929, and 1930, the first, second, and third years of tobacco after the hay crops, black root-rot of tobacco on limed plots was slightly less severe (a little less conspicuous in its effects on the roots) than on plots on which tobacco had been grown every year. This effect was too small, however, to offset the brown root-rot effect of the hay crops on the tobacco which followed them, at least in the first year or two.

Brown root-rot of tobacco following timothy was equally severe on plots with and without lime in 1928, the first year of tobacco. It was much less severe in 1929, the second year after the hay crops. In 1930, the second or third year of tobacco following the hay crops, there was little and in most cases no brown root-rot; that is, the brown root-rot effect of these predisposing crops on the tobacco which followed them disappeared after the first one or two years of tobacco.

In the very rainy season of 1928, lowered yields and poor quality of tobacco were associated with a preceding alfalfa crop only in the lowest part of the field, where all tobacco grew poorly. Tobacco yielded as well after alfalfa as after tobacco in the highest part of the field, and here the tobacco was of as good quality following alfalfa as on plots where only tobacco had been grown. In 1929 limed plots on which alfalfa was grown in 1927 and 1928 yielded 4 to 17 per cent less tobacco than did plots in continuous tobacco; but limed plots on which tobacco was grown no later than 1927 yielded 15 to 30 per cent more tobacco than did limed plots on which tobacco was grown every year. In 1930 the yield of tobacco following alfalfa, grown in 1926 and 1927 or in 1926, 1927, and 1928, was practically the same but no more than the yield on plots in continuous tobacco. The bad effect of brown root-rot on yields of tobacco following alfalfa was, therefore, confined to the first year of tobacco. In the second year of tobacco after alfalfa there was some increase in yield as compared with yield of plots cropped continuously with tobacco; and in the third year, yields were about the same following alfalfa as on plots on which tobacco was grown every year.

With brown root-rot severe, the bad effects of timothy on the yield of tobacco which followed it in 1928 were essentially the same on plots not limed (on which the depressions in yield were 16 to 27 per cent) as on plots limed (on which the depressions in yield were 17 to 33 per cent). In 1929 yields

of tobacco on limed plots on which timothy was grown in 1927 and 1928 were 17 and 37 per cent less than yields on plots cropped continuously with tobacco. Two years of timothy were, therefore, much more injurious than were two years of alfalfa. However, the yield of tobacco the second year after timothy, last grown in 1927, was as good as on plots where tobacco followed tobacco. There was, however, no really increased yield of tobacco on limed plots resulting from the substitution of timothy for tobacco in previous years. In 1930 tobacco on limed plots following timothy yielded as well as (in fact a little better than) tobacco on plots on which only tobacco was grown in earlier years.

Alsike clover was confined to plots not limed, and its effect on the tobacco which followed it may, therefore, be compared only with that of timothy. It was much less injurious than was timothy. Timothy was associated with a loss in yield of tobacco of 81 or 69 per cent in 1928, while the loss in yield of tobacco following alsike clover was 45 or 49 per cent (in duplicate plots).

The substitution of these hay crops for tobacco on limed and Thielavia-infested soils is not to be recommended as a means of increasing soil acidity or overcoming black root-rot in later crops of tobacco.

Effects of Sulfur and of Acids in the Field

On pH Values of Soil

The effects of the several acidification treatments on pH values of soil in limed plots from 1926 to 1930, inclusive, are recorded in Tables 11 to 15. The actual pH values which resulted from each of the several treatments are significant only in connection with this one soil; for as indicated by results in another field described below, and as pointed out by other investigators (23, 21), sulfur (or sulfuric acid) may not give the same results in soils of different types. However, the relatively small changes in pH value of soil which resulted from the application of sulfur or the acids to limed plots were accompanied by materially increased yields of tobacco and less black root-rot.

The pH values of the soil in limed plots to which the acidifying chemicals were applied only in 1926, one month before tobacco plants were set, were as low in that year (pH 5.6 to 5.8) as in the following years; that is, these treatments did not lower the pH value of the soil increasingly after the first year. This is as would be expected, for in experiments by other investigators (26, 15, 30), 80 per cent or more of the sulfur applied to soil was oxidized within a month or during the growing season; and McKibben (23) observed that the acid effect of sulfur applied to soil reached its maximum within two or three months.

The applicaton of sulfuric and orthophosphoric acids in 1926 resulted in sufficiently lowered pH values of the soil (to about 5.7) in 1926 and 1927 but not in 1928 or 1929. The application of these acids in two successive years, 1926 and 1927, resulted in lowered pH values (to 5.6 or 5.7) in every year through 1930. Nine weeks after this treatment was applied in 1927, the pH value of the soil was lowered 0.2 or 0.3 by it.

Sulfur, 400 pounds per acre, applied in 1926 lowered the soil pH values to 5.7 from 5.9 in 1926 and 1927, and it had less but some effect in 1928, 1929 and 1930. The application of 400 pounds of sulfur in 1926 and again in 1927 resulted in lowering the pH values of the soil in 1927, 1928, 1929, and 1930.

Sulfur, 200 pounds per acre, applied in 1926 or in 1926 and 1927 was less

effective than the heavier application: pH values were lowered by it in 1926 and 1927 but not in the following years.

On this heavily limed soil, 400 pounds of sulfur rather than 200 pounds per acre were needed to lower the pH value of the soil effectively. Sulfur, 400 pounds, applied once was effective for two years. Sulfur, 400 pounds, applied in two successive years, 1926 and 1927, remained effective through 1930. In 1930 limed soil not acidified had a pH value of 6.0, and limed soil to which 400 pounds of sulfur had been applied in both 1926 and 1927 had a pH value of 5.7 or a little below the usually accepted danger point for black root-rot.

On Black Root-rot

The severity of black root-rot on limed plots in 1926 was reduced by all acidification treatments but by none of them was it eliminated. The disease was present as a trace on plots not limed, severe on plots limed and not acidified, and moderate or mild to moderate on limed plots acidified, without very pronounced differences between the several acidification treatments.

In 1927 the degree of infection of tobacco by *Thielavia basicola* was greatly reduced by sulfuric and orthophosphoric acids applied in 1926 and 1927. On one of the limed plots so treated, there was no black root-rot and on the other there was only a trace. Black root-rot on the check plots, limed and not acidified, was less severe than the year before, but it was at least moderate in intensity. Infection of tobacco on limed plots was reduced more in 1927 by the application of sulfur in the two successive years than by its application in 1926 only.

In 1928 black root-rot of tobacco was again severe on limed plots and absent, as in every year, from plots not limed. Its severity on limed plots was reduced most this year on those plots to which the acids or sulfur, 400 pounds per acre, was applied in 1926 and 1927; but sulfuric and orthophosphoric acids permitted more infection by Thielavia in 1928 than in 1927, the last year they were applied.

There was black root-rot in 1929 on all tobacco plants on limed plots not acidified, but the infection was no more than moderate. On limed plots, there was least black root-rot on those to which sulfuric and orthophosphoric acids were applied in 1926 and 1927. On these plots there was only a trace of the disease on many of the plants and some of the plants were entirely free from it. The next most nearly disease-free of the limed plots were those to which these acids were applied in 1926. The applications of sulfur, 200 or 400 pounds per acre, in 1926 and 1927 resulted in less black root-rot in 1929 than did the application of these amounts of sulfur in one year (1926) only.

In 1930 black root-rot was no worse than moderate, even on limed plots not acidified. The acidification treatment of limed plots which resulted in least black root-rot this year was the application of 400 pounds of sulfur per acre in 1926 and 1927 or in 1926 only.

On Yields

The percentage increases in yields of limed and acidified plots, for example plots 9a and 21a (duplicates), over yield of check plots 12 and 24, limed but not acidified, may be seen by reference to Table 6. In each case the yield of a limed plot acidified was compared with the yield of the most nearly adjacent limed plot not acidified.

TABLE 6.—INCREASE IN YIELD OF TOBACCO ON LIMED PLOTS RESULTING FROM ACIDIFICATION TREATMENTS OF SOIL.

Plot No.	Acidification treatment (Pounds per acre)	Increase in yield*—per cent 1926	1927	1928	1929	1930
9a, 21a	Sulfur 200, in 1926 and 1927		49.0	None	20.5	11.0
9b, 21b	Sulfur 200, in 1926 only	27.5	34.0	None	14.0	8.0
10a, 22a	Sulfur 400, in 1926 and 1927		43.5	None	14.0	17.0
10b, 22b	Sulfur 400, in 1926 only	34.5	50.5	None	12.5	16.0
11a, 23a	Sulfuric acid 1800 + orthophosphoric acid 440, in 1926 and 1927		87.0	4.5	19.5	18.0
11b, 23b	Sulfuric acid 1800 + orthophosphoric acid 440, in 1926 only	58.5	33.5	20.0	10.5	2.0

* Means for percentage increase in yields of duplicate limed plots acidified, over their most nearly adjacent check plots (limed but not acidified).

Beginning in 1926, the tobacco on limed plots grew much better on those plots which had received applications of sulfur or of sulfuric and orthophosphoric acids than on plots not acidified. The beneficial effect of the acids in 1926 on the growth of plants on limed plots, as compared with growth on limed plots not acidified, is shown in Figure 2. Yields of tobacco on limed plots were increased by all treatments as compared with yields on limed plots not acidified.

The application of sulfur to plots not limed, and therefore without black root-rot as a factor, did not significantly affect yields that year. (In another field with a less well-buffered soil, its pH value two months after the treatments was lowered as follows from an initial pH value of 6.2: by sulfuric acid, 2000 pounds per acre, 0.6; by sulfuric acid, 2000 pounds, and orthophosphoric acid, 500 pounds per acre, 0.6; by orthophosphoric acid, 1000 pounds per acre, 0.3; and by sulfur (inoculated), 400 pounds per acre, 0.4. In the practical absence of *Thielavia basicola* from the soil of this field, none of these treatments affected the yields of tobacco).

In 1927 limed plots to which sulfuric and orthophosphoric acids had been applied for two years (1926 and 1927) yielded as much as plots without lime (and of course without black root-rot). The application of these acids to limed plots for one year only increased yields in 1927 much less than in 1926, the year of application.

Sulfur, 200 or 400 pounds per acre, applied in 1926 increased yields on limed plots more in 1927 than in 1926, the year of its application. Sulfur, 400 pounds per acre, was more effective in increasing yields in both years than was sulfur, 200 pounds per acre.

Sulfur applied to plots not limed, and with black root-rot not a factor, resulted in 1927 either in no effect on yields or in increased yields, as compared with yields of plots not limed and not acidified. Even on unlimed plots 4a and 16a (with soil pH value 5.5) to which sulfur to a total of 800 pounds per acre was applied in 1926 and 1927, yields in 1927 were 6 or 17 per cent larger than the yields of the nearest plots, 6 and 18 respectively, without lime and without acidification. Similarly, on unlimed plots 4b and 16b, to which sulfur, 400 pounds per acre, was applied in 1926, yields were increased in 1927 by 34 and 16 per cent respectively, as compared with yields of nearest plots not limed and with no sulfur. Even these relatively heavy applications

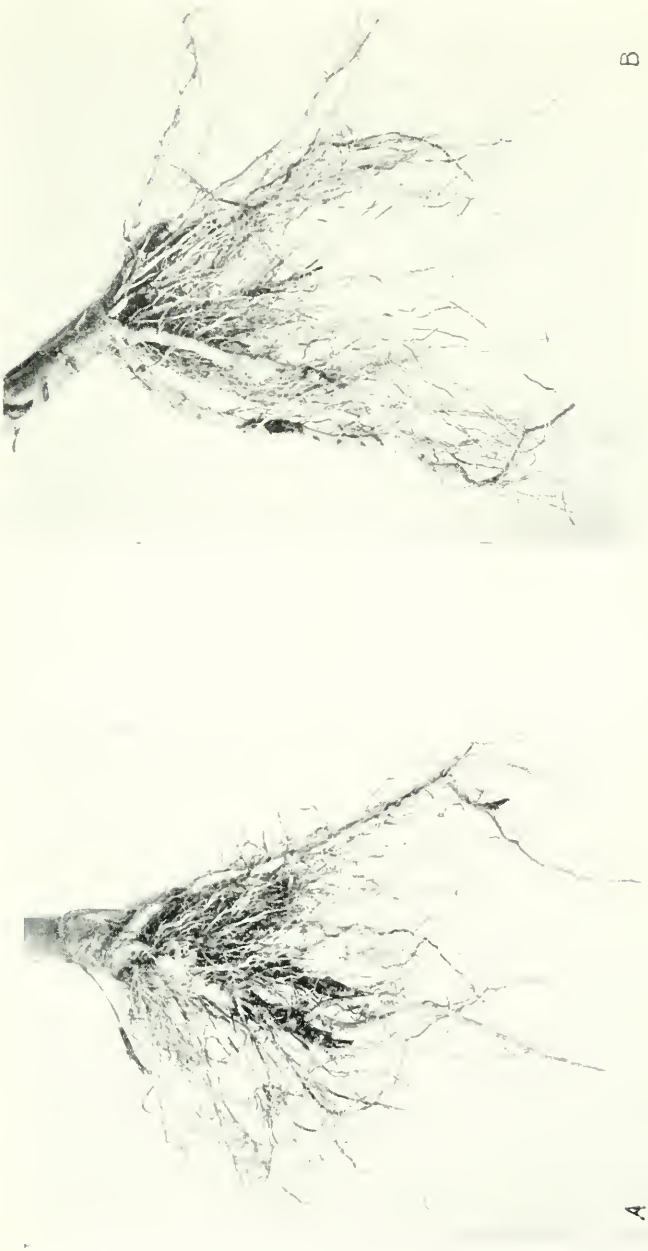

Fig. 1.—Effect of Orthophosphoric Acid on Infection of Tobacco by Thielavia basicola.

A. Typical infection in soil with pH value 5.9 without acid.

B. Typical infection in this soil when its pH value had been lowered to 5.0 by orthophosphoric acid.

Plot 11 is a limed plot to which sulfuric and orthophosphoric acids were applied in 1926.

Plot 12 is a limed plot without acidification.

Fig. 2.—Growth of Tobacco in 1926 on Limed Plots with and without Soil Acidification. (Photographed August 1.)

of sulfur to a relatively acid soil did not interfere with the growth of tobacco. Sulfur did, however, increase yields more on limed plots with black root-rot consequently a factor than on plots not limed.

On the basis of yields in 1927, the optimum rate of application of sulfur for this soil was nearer 400 than 800 pounds per acre. Yields of tobacco on limed plots were increased more in 1927 by sulfur, 400 pounds per acre, applied in 1926 than by sulfur, 400 pounds per acre, applied in 1926 and again in 1927, or a total of 800 pounds.

In 1928, for the first and only time, yields were larger on limed plots than on plots not limed. (Table 13.) In this abnormally rainy season, the effects of sulfur on yields of plots not limed were inconsistent; there were increased yields on some of the plots, following some of the treatments, but on duplicate plots yields were lower than on the check plot without sulfur. Yields on limed plots in 1928 were not consistently increased by sulfur. On the lower part of the field growth was very poor regardless of all factors except too much water in the soil. The yields in 1928 on limed plots to which sulfuric and orthophosphoric acids were applied in 1926 were 21 and 19 per cent greater than those of their checks, plots 12 and 24 respectively, limed but not acidified.

Yields of tobacco in 1929 (Table 14) on limed plots acidified were greater, as in earlier years, than were yields of tobacco on limed plots not acidified. The acidification treatments of limed plots which were most effective in increasing yields were sulfur, 200 pounds per acre applied in 1926 and 1927, and sulfuric and orthophosphoric acids applied two years. The other acidification treatments resulted in increases of from 8 to 14 per cent on limed plots. Acidification treatments of limed plots did not increase yields as much in 1929 as they did in 1926 and 1927. The application of sulfur to plots not limed, and with black root-rot consequently not a factor, did not significantly or consistently affect yields in 1929.

In 1930 the yields of tobacco on limed plots were increased 16, 17, or 18 per cent by sulfur, 400 pounds per acre applied in 1926, the same applied in 1926 and 1927, or the acids applied in 1926 and 1927. (Table 15.) These increases were about the same as those resulting in 1929 from the same treatments; but as in 1929, the increases were much less than in 1926 and 1927, the years of or immediately following the application of the acidifying treatments. In 1930, as in most cases in the earlier years, yields of tobacco on plots not limed were not materially affected by sulfur.

Sulfur (not inoculated) was applied in 1930 to the soil of another field here designated as Field Y, at the rate of 600 pounds per acre. The application was made in April, at which time the pH value of this soil was 7.0. The effects of this application on the pH value of the soil are shown in Table 7.

The pH values of the soil in the plots which received sulfur were lower than those of their checks by 0.2 to 0.6 on July 16. The pH value of this soil was so high in the beginning, however, that although the pH value was lowered as much as to 6.1, it was not enough to prevent black root-rot, and yields of tobacco were unaffected.

In these experiments, then, the application of sulfur to soil increased yields of tobacco markedly and consistently when the soil was infested with Thielavia and when the pH value of the soil was lowered by the sulfur to below 5.9, but not under other conditions.

TABLE 7. EFFECT OF SULFUR ON pH VALUES OF SOIL IN FIELD Y.

Plot No.	Treatment	pH values of soil		
		June 11	July 16	August 27
1	Check	7.0	7.0	7.0
1a	Sulfur	6.1	6.3	6.4
2	Check	7.2	7.0	7.2
2a	Sulfur	6.9	6.8	6.5
3	Check	7.0	7.0	.....
3a	Sulfur	6.9	6.8	.....
4	Check	6.7	6.8	.....
4a	Sulfur	6.3	6.2	.....

On Grades of Leaf

These comparisons are based on the percentages of tobacco from each plot which were sorted into lights, mediums, and seconds, as contrasted with darks and fillers. (See Tables 11-14, for the years 1926, 1927, 1928, and 1929.)

On this basis, the grades as well as the yield of tobacco on limed plots were improved in 1926 and 1927 by the use of sulfur or the acids, sulfuric and orthophosphoric. In 1927, the grades of the tobacco on plots not limed were either improved or unaffected by the applications of sulfur in 1926 and 1927.

Quality was poor on most of the plots in the very rainy summer of 1928 in which the acidification treatments were ineffective in increasing yields. The only treatment which resulted in improved grades of tobacco on limed plots in the lower part of the field that year was the application of sulfuric and orthophosphoric acids in 1926. This treatment as well as sulfur, 200 pounds per acre applied in 1926 or in 1926 and 1927, improved the quality of tobacco on limed plots in the higher part of the field.

In 1929, with larger yields and better quality of tobacco on limed plots than in earlier years, the quality of tobacco was not affected by the acidification treatments either on plots limed or on plots not limed.

In 1930, with black root-rot less severe than in earlier years, the percentage of leaves of the grades lights, mediums, and seconds on limed plots acidified (except by sulfur, 200 pounds per acre applied in 1926) were a little less than the percentages of leaves of these grades on limed plots not acidified.

In 1926, 1927, and 1929, however, the quality of the tobacco was not injured by the sulfur or the acids used on this soil. Similarly, in the experiments of McKibben (23) the quality of tobacco was not affected by sulfur applied to the soil.

On Burn

In experiments of Murwin (25), sulfates (of sodium or magnesium) did not injure the burn of tobacco; but on the basis of other work in Connecticut (8), it was concluded that sulfates in the leaf are injurious to burn, and that the application of sulfates (sulfate of potash) to the soil increases the percentage of sulfates in the leaf. It has been found (8), however, that the ability of the tobacco plant to absorb increased quantities of sulfur is very

limited, which is probably fortunate if sulfur is to be of use in the protection of tobacco against black root-rot.

The effect on burn of tobacco of applications of sulfur to soil limed and not limed may be seen by reference to Table 8.

The fire-holding capacity of the tobacco on limed plots was reduced by the acidification treatments in 1926, the first year of their application and a year of relatively poor burn on all plots. In 1927, the burn of tobacco on limed plots was improved by sulfur, 200 pounds per acre applied in 1926, or in 1926 and 1927, and by sulfuric and orthophosphoric acids applied in 1926: it was not affected significantly or consistently by sulfur, 400 pounds per acre applied in 1926, but it was somewhat injured by sulfur, 400 pounds per acre applied in 1926 and 1927, and by the acids applied in the two years. In 1928 the burn of the tobacco on limed plots was either improved or practically unaffected by all the acidification treatments. In 1929 the fire-holding capacity of the leaf on limed plots was not reduced by the acids or by sulfur one year, but sulfur, 400 pounds per acre for two years, was associated with a poorer burn.

Considering now the burn of the tobacco on plots not limed, it appears that in 1927 the fire-holding capacity was reduced somewhat, although not consistently, by all the acidification treatments except the smallest application of sulfur; in 1928 it was either improved or practically unaffected by the acidification treatments; and in 1929 it was somewhat reduced by all acidification treatments.

However, applications of sulfur such as these would be made only to limed soil and when black root-rot made such treatments advisable; and when there were any differences, sulfur reduced fire-holding capacity more on plots not limed than on plots limed.

The amount of sulfur which may be used on tobacco land infested with Thielavia depends on the initial pH value of the soil on the one hand, and on the effect of too much sulfur on burn on the other hand. On heavily limed soil under the conditions here described, loss caused by black root-rot was reduced without injury to burn by one application of sulfur of 200 or 400 pounds per acre; but when these applications were repeated the following year, on the same plots, fire-holding capacity was impaired.

SUMMARY

Effects of acids and of sulfur in lowering the pH values of soil and on growth and black root-rot of tobacco are described.

When the pH value of soil was lowered by the application of sulfuric or nitric acids, infection by Thielavia was reduced accordingly.

When the pH value of soil was lowered, as from 5.9 to 5.0, by the application of orthophosphoric acid (alone), black root-rot of tobacco was still severe or even more severe. It is possible that salts of aluminum, instead of or in addition to hydrogen-ion concentration, inhibit *Thielavia basicola* in acid soils, and that orthophosphoric acid as well as lime inactivates such toxic substances, with consequent benefit to the fungus. An application of aluminum sulfate to the soil was found to reduce injury to tobacco caused by this fungus.

Soil pH values in field plots to which lime was last applied in 1923 were still high enough in 1930, above 5.9, to be favorable to *Thielavia basicola*.

TABLE 8.—EFFECTS OF SULFUR AND OF SULFURIC AND ORTHOSPHORIC ACIDS ON FIRE-HOLDING CAPACITY OF TOBACCO.

Plot No.	Lime treatment	Acidification treatment (Pounds per acre)	1926 crop		1927 crop		1928 crop		1929 crop	
			Seconds	Darks	Seconds	Darks	Seconds	Darks	Seconds	Darks
			Seconds	*Seconds*	*Seconds*	*Seconds*	*Seconds*	*Seconds*	*Seconds*	*Seconds*
9b, 21b	Lime	Sulfur 200, in 1926	8.1	4.2	18.7	19.4	49.5	70.5	29	21
9a, 21a	Lime	Sulfur 200, in 1926 and 1927			17.7	20.5	45.5	41.0	18	15
10b, 22b	Lime	Sulfur 400, in 1926	7.5	5.6	10.6	14.5	42.0	48.0	25	12
10a, 22a	Lime	Sulfur 400, in 1926 and 1927			9.3	8.9	35.5	45.5	16	9
11b, 23b	Lime	Sulfuric acid 1800 + orthophosphoric acid 440, in 1926	4.2	5.3	14.9	13.9	33.5	38.5	23	12
11a, 23a	Lime	Sulfuric acid 1800 + orthophosphoric acid 440, in 1926 and 1927			8.3	8.0	24.5	26.5	25**	18**
12, 24	Lime	None	11.1	9.5	12.9	9.4	30.5	25.5	29	15
3b, 15b	None	Sulfur 200, in 1926			11.0	15.4	32.5	48.5	11	11
3a, 15a	None	Sulfur 200, in 1926 and 1927			5.7	13.4	29.5	36.5	23	11
4b, 16b	None	Sulfur 400, in 1926			10.8	5.6	24.0	23.5	15	9
4a, 16a	None	Sulfur 400, in 1926 and 1927			9.6	5.6	31.5	30.5	11	17
5, 6, 17, 18†	None	None	8.9	5.9	11.8	9.6	26.0	35.2	26	18

* Means for duplicate plots. ** Only Plot 23a. † Plots 5 and 17 in 1926.

Loss in yield of tobacco, caused directly by black root-rot and indirectly by lime, reached its maximum (about 44 per cent) in 1925 and 1926, the second and third years after lime was last applied. In subsequent years, this loss in yield on limed plots (in all cases as compared with yields on plots not limed) decreased so that it was about 24 per cent in 1929 and 1930.

Lowered yields on limed plots were usually associated with poorer quality.

In four out of six years, lime did not increase the fire-holding capacity of the leaf, as determined in strip tests. Abundant rainfall was associated with improved burn and had more effect than did lime on the length of time leaves held fire.

Tobacco and alfalfa were equally efficient, and much more efficient than timothy, in removing calcium and magnesium oxides from limed soil; but with no sulfur or acids applied, none of these crops caused a lowering of the pH value of the soil between 1926 and 1930.

Thielavia basicola did not infect alfalfa grown in limed soil infested with this fungus. As far as black root-rot is concerned, there is probably no reason why alfalfa cannot be grown in a rotation preceding tobacco.

The substitution of a hay crop for tobacco on over-limed, Thielavia-infested soil is not to be recommended as a means of overcoming black root-rot of later crops of tobacco.

Following timothy, brown root-rot of tobacco was equally severe on plots limed and on plots not limed.

Alfalfa or alsike clover as a cause of brown root-rot of tobacco was much less injurious than was timothy. In the second year of tobacco following alfalfa on limed soil infested with *Thielavia basicola*, there were marked increases in yields of tobacco as compared with yields of tobacco on plots on which tobacco was grown every year; but in 1930 tobacco following alfalfa (last grown in 1927 or 1928) yielded no more than did continuous tobacco.

The pH value of soil was lowered as much, or more, the year sulfur or acids were applied as in the years following. Soil pH values were lowered for four years by sulfur, 400 pounds per acre, but sulfur, 200 pounds per acre, was not enough in this soil to keep the pH value low.

The severity of black root-rot was lessened by all acidification treatments in the year of their application. Sulfur, 400 pounds per acre applied two years in succession, lessened the severity of black root-rot in these and the three following years.

Yields of tobacco on limed plots infested with *Thielavia basicola* were increased by all acidification treatments the first year the materials were applied. The application of sulfur to plots not limed, and on which there was no black root-rot, either increased yields of tobacco somewhat or did not affect them. Sulfur applied to limed plots increased yields more in the year following than in the year of its application. The optimum rate of application of sulfur to this soil, as evidenced by yields of tobacco as well as effect on burn, was nearer 400 than 800 pounds per acre. Increased yields from some of the acidification treatments have continued up to the present (1930).

Increased yields associated with acidification treatments of limed plots were accompanied in general by increased percentages of leaves of the grades lights, mediums, and seconds (as contrasted with darks and fillers).

The application of sulfur, 400 pounds per acre in one year, to limed plots reduced the fire-holding capacity of the tobacco in the year in which it was applied but not in the three years following. This is considered to be the maximum application which is safe on this soil.

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APPENDIX

TABLE 9.—SOIL TREATMENTS AND CROPS OF EACH PLOT IN EACH YEAR.

Lime ment treat-	1926			1927			1928			1929 and 1930	
	No. Plot	Acidification treatment	Crop	Plot No.	Acidification treatment	Crop	Plot No.	Crop		Plot No.	Crop
		Pounds per acre			*Pounds per acre*						
None	1	None	Alsike Clover	1	None	Alsike clover	1a	Tobacco		1a	Tobacco
							1b	Alsike clover		1b	Tobacco
None	2	None	Timothy	2	None	Timothy	2a	Timothy		2a	Tobacco
							2b	Tobacco		2b	Tobacco
None	3	Sulfur 200	Tobacco	3a	Sulfur 200	Tobacco	3a	Tobacco		3a	Tobacco
				3b	None	Tobacco	3b	Tobacco		3b	Tobacco
None	4	Sulfur 400	Tobacco	4a	Sulfur 400	Tobacco	4a	Tobacco		4a	Tobacco
				4b	None	Tobacco	4b	Tobacco		4b	Tobacco
None	5	None	Tobacco	5	None	Tobacco	5	Tobacco		5	Tobacco
None	6	None	Tobacco	6	None	Tobacco	6	Tobacco		6	Tobacco
Lime	7	None	Alfalfa	7	None	Alfalfa	7a	Tobacco		7a	Tobacco
							7b	Alfalfa		7b	Tobacco
Lime	8	None	Timothy	8	None	Timothy	8a	Timothy		8a	Tobacco
							8b	Tobacco		8b	Tobacco
Lime	9	Sulfur 200	Tobacco	9a	Sulfur 200	Tobacco	9a	Tobacco		9a	Tobacco
				9b	None	Tobacco	9b	Tobacco		9b	Tobacco
Lime	10	Sulfur 400	Tobacco	10a	Sulfur 400	Tobacco	10a	Tobacco		10a	Tobacco
				10b	None	Tobacco	10b	Tobacco		10b	Tobacco

Lime	11	Sulfuric acid 1800 + orthophosphoric acid (80%) 440	Tobacco	11a	Acids again as in 1926	Tobacco	11a	Tobacco	11a Tobacco
				11b	None	Tobacco	11b	Tobacco	11b Tobacco
Lime	12	None	Tobacco	12	None	Tobacco	12	Tobacco	12 Tobacco
None	13	None	Alsike clover	13	None	Alsike clover	13a	Tobacco	13a Tobacco
							13b	Alsike clover	13b Tobacco
None	14	None	Timothy	14	None	Timothy	14a	Timothy	14a Tobacco
							14b	Tobacco	14b Tobacco
None	15	Sulfur 200	Tobacco	15a	Sulfur 200	Tobacco	15a	Tobacco	15a Tobacco
				15b	None	Tobacco	15b	Tobacco	15b Tobacco
None	16	Sulfur 400	Tobacco	16a	Sulfur 400	Tobacco	16a	Tobacco	16a Tobacco
				16b	None	Tobacco	16b	Tobacco	16b Tobacco
None	17	None	Tobacco	17	None	Tobacco	17	Tobacco	17 Tobacco
None	18	None	Tobacco	18	None	Tobacco	18	Tobacco	18 Tobacco
Lime	19	None	Alfalfa	19	None	Alfalfa	19a	Tobacco	19a Tobacco
							19b	Alfalfa	19b Tobacco
Lime	20	None	Timothy	20	None	Timothy	20a	Timothy	20a Tobacco
							20b	Tobacco	20b Tobacco
Lime	21	Sulfur 200	Tobacco	21a	Sulfur 200	Tobacco	21a	Tobacco	21a Tobacco
				21b	None	Tobacco	21b	Tobacco	21b Tobacco
Lime	22	Sulfur 400	Tobacco	22a	Sulfur 400	Tobacco	22a	Tobacco	22a Tobacco
				22b	None	Tobacco	22b	Tobacco	22b Tobacco
Lime	23	Sulfuric acid 1800 + orthophosphoric acid (80%) 440	Tobacco	23a	Acids again as in 1926	Tobacco	23a	Tobacco	23a Tobacco
				23b	None	Tobacco	23b	Tobacco	23b Tobacco
Lime	24	None	Tobacco	24	None	Tobacco	24	Tobacco	24 Tobacco

TABLE 10.—FERTILIZERS APPLIED EACH YEAR. (POUNDS PER ACRE.)

Fertilizer materials	1926	1927	1928	1929	1930
Ammo-Phos	216.2	236			
Fish	200.0	200			
Calcium nitrate	143.5	89	117.0		
Cottonseed meal	922.5	908	1107.6	1107.6	1107.6
Sulfate of potash-magnesia	233.9	247	283.0	293.9	293.9
Sulfate of potash (high grade)	131.0	131			
Urea			72.5		
Nitrate of potash			166.1	173.7	173.7
Precipitated bone			368.4	350.0	350.0
Calurea				107.2	107.2
Nitrate of Soda				92.4	92.4
Equivalent to a 5-4-5 fertilizer	3000	3000	3500	3500	3500

TABLE 11.—SOIL REACTION, DISEASE CONDITIONS, AND YIELD AND QUALITY OF TOBACCO IN 1926.

Plot No.	pH values of soil			Black root-rot of tobacco	Yields of tobacco per acre	Lights, mediums, and seconds	Length of time leaves held fire	
	April*	June 5	Aug. 5				Seconds	Darks
					Pounds	*Per cent*	*Seconds*	*Seconds*
1	5.5		5.5					
2	5.4		5.5					
3	5.4	5.4	5.4	Trace	1670			
4	5.3	5.3	5.4	Trace	1562			
5	5.4	5.4	5.5	Trace	1642	50	9.1	6.8
6	5.4	5.4	5.5	Trace	1688			
7	5.8		5.9					
8	5.9		5.9					
9	5.8	5.75	5.7	Moderate	1126	38	10.0	4.4
10	5.8	5.6	5.6	Moderate to mild	1241	21	7.3	6.0
11	5.8	5.5	5.7	Moderate to mild	1450	36	4.1	5.7
12	5.9	5.85	5.9	Severe	867	22	14.3	9.5
13	5.4		5.4					
14	5.5		5.6					
15	5.4	5.4	5.5	Trace	1638			
16	5.4	5.4	5.4	Trace	1560			
17	5.5	5.5	5.5	Trace	1662	46	8.8	5.1
18	5.4	5.45	5.5	Trace	1608			
19	5.8		5.8					
20	5.8		5.8					
21	5.9	5.75	5.8	Moderate	1264	39	6.3	4.0
22	5.8	5.75	5.7	Moderate to mild	1267	39	7.9	5.2
23	5.8	5.7	5.7	Moderate to mild	1500	28	4.3	4.9
24	5.9	5.9	5.9	Severe	1003	30	8.0	9.5

* Before acidification.

TABLE 12.—SOIL REACTION, DISEASE CONDITIONS, AND YIELD AND QUALITY OF TOBACCO IN 1927.

Plot No.	pH values of soil			Black root-rot of tobacco	Yields of tobacco per acre	Lights, Mediums, and seconds	Length of time leaves held fire	
	April 4	June 22	Sept. 2				Seconds	Darks
					Pounds	*Per cent*	*Seconds*	*Seconds*
1	5.7	..	5.7	...			.	
2	5.7	.	5.8	...				
3a	5.7	5.5	5.5	None	1876	29	6.5	8.0
3b	5.7	5.6	5.6	None	1785	28	9.0	19.1
4a	5.7	5.5	5.5	None	1542	17	10.8	5.2
4b	5.7	5.5	5.6	None	1951	32	12.0	6.0
5	5.6	5.6	5.7	None	1712	24	12.2	17.5
6	5.7	5.5	5.6	None	1452	19	9.8	5.9
7	5.9	.	5.9			...	...	...
8	5.9	..	6.0			.	.	...
9a	5.8	5.8	5.8	Very mild	1408	15	13.5	26.0
9b	5.8	5.8	5.8	Moderate	1245	30	24.2	25.7
10a	5.7	5.6	5.7	Trace to mild	1316	12	10.1	8.4
10b	5.7	5.7	5.8	Mild	1395	10	13.3	12.4
11a	5.7	5.7	5.6	None	1735	19	10.2	10.8
11b	5.7	5.7	5.8	Mild	1200	16	20.8	11.5
12	5.8	5.9	5.9	Moderate	892	6	6.2	10.6
13	5.7	...	5.6	...	...	...	.....	...
14	5.7	.	5.8	...				
15a	5.6	5.5	5.5	None	1906	31	5.0	7.7
15b	5.6	5.6	5.6	None	1821	24	13.0	11.4
16a	5.6	5.5	5.5	None	1903	33	8.4	6.0
16b	5.6	5.5	5.6	None	1887	33	9.6	5.3
17	5.7	5.6	5.7	None	1854	28	13.6	8.5
18	5.6	5.5	5.7	None	1620	35	11.7	6.5
19	5.9	.	5.9		.			. .
20	5.9		5.9			.		
21a	5.9	5.7	5.8	Mild to moderate	1512	18	22.0	15.1
21b	5.9	5.8	5.9	Moderate	1395	23	13.2	13.1
22a	5.8	5.7	5.8	Very mild	1506	23	8.6	9.4
22b	5.8	5.7	5.8	Mild	1573	28	8.0	16.7
23a	5.8	5.6	5.7	None*	1932	25	6.4	5.3
23b	5.8	5.7	5.8	Mild	1427	30	9.1	16.3
24	5.9	5.9	5.9	Moderate	1082	18	19.6	8.2

* Trace on one.

TABLE 13.—SOIL REACTION, DISEASE CONDITIONS, AND YIELD AND QUALITY OF TOBACCO IN 1928.

Plot No.	pH values of soil July 27	pH values of soil Sept. 10	Black root-rot of tobacco	Brown root-rot of tobacco	Yields of tobacco per acre	Lights, mediums, and seconds	Length of time leaves held fire Seconds	Length of time leaves held fire Darks
					Pounds	*Per cent*	*Seconds*	*Seconds*
1a	5.1	5.0	Trace	Severe	401	11	32	30
1b	5.3	4.7	.....	.....	.....	.....	..	.
2a	5.7	5.5	.....	.....	.....	.....	..	.
2b	5.6	5.6	None	Severe	273	0	.	16
3a	4.8	5.0	None	Trace	727	2	38	21
3b	5.2	5.2	None	None	666	13	33	50
4a	4.7	4.6	None	None	844	6	23	35
4b	5.5	5.1	None	None	844	10	24	31
5	5.2	5.4	Trace	None	784	15	25	42
6	5.2	5.1	None	Trace to mild	662	12	34	23
7a	6.5	6.3	Mild to moderate	Very severe	270	0	.	
7b	6.3	6.6	.....	.....	.....	.....		
8a	6.5	6.8	.....	.....	.....	.....		
8b	6.6	6.8	Moderate	Severe	167	0	.	.....
9a	6.3	6.2	Moderate to severe	Trace to mild	480	3	59	32
9b	6.2	6.1	Moderate to severe	Mild	562	2	62	78
10a	5.9	5.8	Mild	None	710	20	33	51
10b	6.1	6.1	Moderate to severe	Trace to mild	711	14	38	51
11a	5.5	5.9	Mild to moderate	Trace to mild	750	15	29	33
11b	6.1	6.1	Mild to moderate	Trace	1058	37	41	41
12	6.1	6.0	Severe	Mild	874	17	36	16
13a	5.5	5.3	None	Severe	450	4	17	23
13b	5.5	5.3	.....	.....	.....	.....	. .	.
14a	5.7	5.3	.....	.....	.....	..		
14b	5.6	5.8	None	Severe	279	0		
15a	5.2	5.2	None	Trace	705	12	21	52
15b	5.2	5.2	None	None	632	4	32	47
16a	4.7	5.0	None	Trace	720	10	40	26
16b	5.0	5.3	None	Trace	690	6	24	16
17	5.2	5.2	None	Trace	865	35	25	41
18	5.3	5.2	None	None	917	27	22	35
19a	6.1	6.3	Mild	Moderate to severe	940	28	38	46
19b	6.3	6.5	.....	.....	.....	..	.	
20a	6.3	6.6	.	.	.	.		
20b	6.3	6.1	Moderate to severe	Severe	484	4	36	22
21a	6.1	6.0	Mild to moderate	Trace	994	36	32	50
21b	5.8	6.0	Moderate	None	918	19	37	63
22a	5.3	5.9	Moderate	Trace	1055	18	38	40
22b	5.7	6.0	Moderate to severe	None	1044	17	46	45
23a	5.6	6.0	Mild	None	1185	15	20	20
23b	6.0	6.0	Mild to moderate	None	1155	27	26	36
24	6.1	6.0	Severe	None	966	25	25	35

TABLE 14.—SOIL REACTION, DISEASE CONDITIONS, AND YIELD AND QUALITY OF TOBACCO IN 1929.

Plot No.	pH values of soil		Black root-rot of tobacco	Brown root-rot of tobacco	Yields of tobacco per-acre	Lights, mediums, and seconds	Length of time leaves held fire	
	May 20	Sept. 3					Seconds	Darks
					Pounds	*Per cent*	*Seconds*	*Seconds*
1a	5.4	5.3	None	Trace	960	34	14	12
1b	5.3	5.2	None	Mild	1329	34	6	7
2a	5.3	5.3	None	Moderate	1125	29	24	6
2b	5.4	5.3	None	Mild	1372	36	13	7
3a	5.0	4.7	None	None	1500	33	15	11
3b	5.2	5.2	None	None	1473	37	14	12
4a	5.0	4.7	None	None	1366	24	12	17
4b	5.4	5.0	None	None	1545	37	6	8
5	5.2	5.3	None	None	1436	35	17	8
6	5.2	5.4	None	None	1556	45	46	23
7a	6.3	5.8	Mild to moderate	Moderate	1504	32	20	20
7b	6.3	5.8	Mild	Severe	967	20	12	5
8a	6.3	5.7	Trace to mild	Severe	780	21	25	9
8b	6.3	6.3	Trace to mild	Moderate to severe	1217	34	8	8
9a	6.1	5.9	Trace	.....	1390	34	20	13
9b	6.2	5.9	Mild	.....	1291	35	32	30
10a	5.6	5.7	Trace to mild	.....	1320	36	28	11
10b	5.9	5.7	Trace to mild	.....	1330	36	38	11
11a	5.7	5.6	Trace	.....	1393	33	...	...
11b	6.0	5.8	Trace	.....	1249	31	20	15
12	6.2	6.0	Mild to moderate	.....	1159	34	27	15
13a	5.5	5.3	None	Mild	1466	32	7	8
13b	5.3	5.1	None	Trace to mild	1286	18	4	5
14a	5.2	5.3	None	Trace	1245	13	6	5
14b	5.7	5.3	None	Trace	1462	36	28	24
15a	5.3	5.1	None	None	1662	32	32	12
15b	5.1	5.2	None	None	1572	36	9	11
16a	5.0	5.0	None	None	1572	28	10	17
16b	5.0	5.0	None	None	1508	30	24	10
17	5.3	5.2	None		1506	36	23	18
18	5.3	5.2	None		1482	33	17	22
19a	6.1	6.1	Mild	Trace to mild	1360	45	12	8
19b	6.0	6.0	Trace	Moderate to severe	1135	24	5	3
20a	6.3	6.1	Trace to mild	Moderate to severe	975	22	4	5
20b	6.4	6.2	Trace to mild	.....	1228	28	7	7
21a	5.9	6.0	Mild to moderate	.....	1426	39	13	17
21b	5.9	5.8	Mild to moderate	Trace	1385	43	27	12
22a	5.7	5.5	Trace to mild	None	1345	34	5	8
22b	5.7	6.0	Trace to mild	None	1300	35	12	13
23a	5.6	5.6	Trace	None	1411	35	25	18
23b	6.0	5.8	Trace	.....	1330	35	27	9
24	6.3	6.0	Mild to moderate	.....	1181	40	32	15

TABLE 15. SOIL REACTION, DISEASE CONDITIONS, AND YIELD AND QUALITY OF TOBACCO IN 1930.

Plot No.	pH values of soil August 27	Black root-rot of tobacco	Brown root-rot of tobacco	Yields of tobacco per-acre	Lights, mediums, and seconds
				Pounds	*Per cent*
1a	5.2	None	None	1787	48
1b	5.0	None	None	1725	48
2a	5.2	None	None	1802	45
2b	5.3	None	Trace	1889	38
3a	5.0	None	None	1978	43
3b	4.9	None	None	1926	52
4a	4.8	None	None	1740	48
4b	4.9	None	None	1831	47
5	5.2	None	None	1848	51
6	5.0	None	None	1888	50
7a	6.1	Mild	None	1216	52
7b	5.8	Trace to mild	Moderate	1124	48
8a	6.0	Mild to moderate	Moderate	1339	43
8b	5.9	Moderate	None	1368	49
9a	5.7	Trace to mild	Trace to mild	1458	41
9b	5.8	Moderate to severe	None	1428	39
10a	5.4	Trace to mild	Trace	1592	41
10b	5.9	Trace to mild	None	1573	42
11a	5.5	Mild to moderate	None	1592	34
11b	5.5	Trace to mild	Moderate	1329	37
12	5.8	Moderate to severe	None	1476	50
13a	4.7	None	None	1757	37
13b	5.0	None	Trace to mild	1654	45
14a	5.1	None	None	1797	39
14b	4.9	None	None	1874	54
15a	4.7	None	None	2052	48
15b	5.0	None	None	1978	48
16a	4.5	None	None	2018	45
16b	4.8	None	None	1872	46
17	5.1	None	None	1921	45
18	4.9	None	None	2039	45
19a	6.1	Mild	None	1524	50
19b	6.1	None	Trace	1577	43
20a	6.3	Mild to moderate	None	1661	53
20b	6.3	Mild to moderate	None	1585	47
21a	6.3	Mild to moderate	None	1657	53
21b	6.2	Mild	None	1589	63
22a	6.0	Trace to mild	None	1677	49
22b	5.7	Trace to mild	None	1667	37
23a	5.8	Mild	None	1703	43
23b	5.9	Mild to moderate	None	1517	43
24	6.1	Mild to moderate	None	1324	49

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE.
3M-7-'31. No. 2887.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 277 October, 1931

Flower Pot Composition and Its Effect on Plant Growth

By Linus H. Jones

The ordinary flower pot of fired clay has been the standard plant container for many years. In recent years, however, flower pots of other materials have come on the market; and of these, paper pots have received most consideration because of their economic advantages. A result of this interest has been a pronounced demand for reliable information concerning the comparative merits of different types of containers. The investigation reported in this bulletin was begun in response to this demand and has given results which are applicable either to the production of greenhouse plants in wholesale quantities or to the growing of a single house plant.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

FLOWER POT COMPOSITION AND ITS EFFECT ON PLANT GROWTH

By Linus H. Jones,[1] Assistant Research Professor of Botany

Introduction

An investigation of the merits of several types of plant containers has revealed some interesting problems, the solution of which is of value to both the producers and users of flower pots. The standard porous clay pot, with drainage hole in the bottom, is in general use wherever plants are grown in containers. With a good potting soil, proper temperature, water, and sufficient light, the attendant in a greenhouse knows he can produce good plants in such pots. When these same plants with their containers are removed to the rooms where man works and dwells, experience indicates that the plant will lose its luxuriance and may even die. Among the excuses for failure to grow house plants may be mentioned the dryness of the air, the presence of coal gas, and a natural lack of sympathetic understanding with the plants. The paramount picture of household plants is the uncanny success of the poor people with their tin-can containers. To all appearances, these people have disobeyed all the rules of culture in that the non-porous containers with inadequate drainage are in kitchens with a great range of temperature, where coal gas is frequently present, and where the sunlight is frequently of short duration.

The Porous Clay Flower Pot

Many examinations of house plants that are gradually dying have shown a general absence of insect pests and freedom from disease. However, when the plant is removed from its pot, it is usually quite noticeable that the porous pot itself is dry, that the upper third of the soil is wet and the lower half of the soil is powder dry. In this dry soil the roots are dead. The diagnosis from the conditions thus found is gradual death of the plant caused by a lack of moisture in the area normally occupied by the feeding roots.

An investigation of a broad nature has brought out some generalities that explain a great many failures in growing house plants. A knowledge of these factors leads to recommendations which may insure the successful home culture of plants with a minimum amount of care.

It is well known that warm air will hold more moisture than cool air When the cool air of winter is introduced into our rooms and its temperature raised by any heating apparatus, the little moisture that it originally contained when cool is very small compared with the amount of moisture the

[1] The writer is indebted to Professor A. Vincent Osmun, Head of the Department of Botany, for his keen interest in aiding in the solution of the many problems encountered in this investigation, and for his suggestions in making the results of greater service to the public.

air can retain at the raised temperature. The ratio obtained by comparing the moisture actually present with the greatest amount of moisture the air could possibly contain at a given temperature is called the *relative humidity*, with 100 per cent as the highest possible value. In the locality of Amherst, Massachusetts, the normal out-of-door relative humidities for the months of June, July, and August are respectively 74, 76, and 78 per cent (5). The driest atmosphere in North America is in Death Valley, California, where an observer has recorded a relative humidity as low as 23 per cent. This humidity is low, and yet the writer on several occasions has found the humidity of rooms in an average building to be as low as 20 per cent. In Canada, where the winter air is much cooler than in Amherst, relative humidity as low as 8 per cent has frequently been recorded (12). There has been so little work done in obtaining actual measurements of the relative humidity in homes that little information is available. Daniels (3) states it is probable that our homes have a relative humidity of 20 per cent or lower. Such a low humidity indicates an atmosphere as dry as desert air.

The effect of such a low moisture content is an atmosphere with a high evaporating power. This increased evaporating power of the air quickly takes up the moisture from the outside of the porous flower pot. The moisture lost from the pot is replaced by moisture from the soil and the process continues until both pot and soil are dry, if the soil remains in intimate contact with the pot. Usually, however, this extreme is never reached, as the daily watering of the plants provides sufficient moisture to partially replace the daily loss. As a matter of fact, practically one-half of the normal amount of water supplied may be taken up by the pot, if the pot is dry. In Table 1 are given the actual amounts of water adsorbed by dry flower pots of various sizes and also the amounts of water that constitute a normal watering for these pots.

TABLE 1.—THE VOLUME OF A NORMAL WATERING OF A CLAY FLOWER POT THAT IS ADSORBED BY THE POT.

Size of pot	Normal watering	Adsorbed by pot	Water available for plant
Inches	*C. c.*	*C. c.*	*C. c.*
3	54	25	29
4	100	57	43
5	200	86	114
6	300	132	168
7	500	163	337

If the evaporation of water from the pot plus the amount used by the plant exceeds the amount applied, there is a deficit of normal moisture in the soil. This deficit may gradually increase until the soil is entirely devoid of moisture in the lower part of the pot. When this occurs the feeding roots die and the above-soil portions of the plant die either gradually or quickly according to the nature of the plant or the rapidity with which this moisture deficit develops. The normal daily water that is applied does not evenly distribute itself throughout the soil. The attraction by the pot itself for the water causes a movement of the capillary water to the pot which usually reduces the moisture in the upper part of the soil before it has had time to penetrate the lower and drier layer of soil.

The evaporation of moisture from the outside surface area of the porous

pot has a cooling effect on the soil. Experiments conducted by Jones (7) show that a difference of 20° F. may exist between the soil temperatures of a clay pot and a non-porous pot, the clay pot being the cooler. By weighing at frequent intervals, it was found that twice as much water was lost from the porous pot as from the non-porous pot. In Table 2 is shown the loss of weight from porous and non-porous three-inch flower pots and the temperature at the center of the soil mass. As the surface areas of the two types of pots were the same, the greater moisture loss in the porous pots was due to the evaporation from the outside surface of the pot itself. This double loss of moisture from the porous pots was again checked in a later phase of the investigation which brought out the fact that the porous pots required twice as much attention for watering as did the non-porous pots.

TABLE 2.—THE LOSS OF MOISTURE FROM POROUS AND NON-POROUS POTS AND THE EFFECT OF EVAPORATION ON SOIL TEMPERATURE IN THESE CONTAINERS.

Time	LOSS OF MOISTURE				SOIL TEMPERATURE			
	Porous pots		Non-porous pots		Porous pots		Non-porous pots	
	Grams	*Grams*	*Grams*	*Grams*	°*C.*	°*C.*	°*C.*	°*C.*
9:00 a.m.	0	0	0	0	11	11	11	11
1:30 p.m.	27.8	30.8	11.3	12.1	27	27	38	38
2:00	3.0	3.3	0.9	0.6	26	26.5	38	38
2:30	2.9	2.6	1.6	1.5	26	27	38	38
3:00	2.6	3.4	0.6	0.8	26	27	37	38
3:30	2.3	1.9	1.7	0.9	27	28	37	38
TOTAL	38.6	42.0	16.1	15.9				

However, there has been no indication that the excessive evaporation from the porous pots affects the growth of the plant from the temperature angle. There is sufficient evidence to state that the excessive evaporation ultimately leads to a water deficit in a portion of the soil and that this deficit is not made up by the daily practice of watering.

If, however, the tin can or some other non-porous container is used, there can be no adsorption of moisture by the container and hence no evaporation on the outside surface. All the water applied is evenly distributed and kept in balance throughout the soil mass. The range of moisture content is much smaller than in the porous container and the response by the plant is consequently a steady growth, if temperature and light are suited to the plant.

If porous containers are to be used in rooms where the relative humidity is low, it is advisable to keep such containers on a moist surface. This is best secured by resting them on a shallow mass of moist sphagnum moss, such as is used by florists for making funeral set pieces. The porous pot will continue to evaporate its moisture, but will replenish the loss by taking up the moisture from the moss. Standing porous pots in free water may be practised, but this method may lead to a water-soaked soil and consequent lack of aeration in the soil.

Paper Flower Pots

Paper flower pots may be successfully employed for growing plants, if the paper is properly impregnated with a substance that will prevent the de-

composition of the paper fibers. This water-proofing material must also be harmless to the root system, a part of which will be in direct contact with the inside wall of the pot. Because of the lack of porosity in a properly made paper flower pot, plants will frequently do better in these paper pots than in the standard clay pots.

In cooperation with an industrial concern in Massachusetts[2], a thorough investigation has been made of what the requirements of a paper pot should be to insure proper growth of plants. Growers who were using paper pots, water-proofed with paraffin, claimed that poor growth was obtained in these pots because of an acid condition in the soil resulting from a lack of aeration through the wall of the pot. That this premise probably is not well-founded is shown by the fact that plants grown in glass containers have proved to be superior to plants grown in porous containers. In Figure 3 are shown tomato, pepper, and calendula plants growing in porous pots (clay) and extremely non-porous containers (jelly glasses). Figure 3 also shows the poor growth obtained in pots made of paraffined paper. It is quite evident that the lack of porosity in the paper pot is not a factor that hinders normal growth. Sufficient aeration of the soil may be obtained easily through the surface in the same way that aeration occurs in the field and forest.

Since porosity is not a factor, attention was directed to the soil temperature as affected by the materials used in making plant containers (7). The cooling effect by evaporation from a porous pot was sufficient to maintain a soil temperature 20° F. lower than that of a glass container. The temperature of the soil in a glass container followed closely the fluctuations of temperature of the air of the greenhouse. The temperature of the soil mass in a paper pot lagged about 3° F. behind the soil temperature of the glass container.

TABLE 3.—TEMPERATURES OF SOIL MASS IN THREE-INCH PLANT CONTAINERS OF DIFFERENT COMPOSITION.

Time	Standard pot °F.	Paper pot °F.	Peat pot °F.	Fiber pot °F.	Glass tumbler °F.
8:30 a.m.	64	67	64	65	68
9:00	77	82	73	73	82
9:30	83	91	79	79	93
10:00	85	95	82	84	99
10:30	85	99	84	86	102
11:00	85	100	84	88	104
11:30	86	100	84	90	105
12:00 m.	86	102	85	90	105
12:30 p.m.	85	102	84	90	105
1:00	85	102	85	91	105
1:30	86	102	86	91	105
2:00	86	102	86	91	105
2:30	86	102	86	91	105
3:00	86	102	86	91	105
3:30	86	102	86	91	105
4:00	86	102	86	91	105
4:30	86	103	86	91	105

In Table 3 is given the half-hourly readings of soil temperatures obtained from a few types of plant containers. The paper pot, in a warm greenhouse,

[2] Bird and Son, East Walpole, Massachusetts.

did have a soil temperature considerably higher than that of a porous pot. However, no experimental evidence could be obtained which would indicate any effect on plant growth. Tomato plants in clay, paper, and glass containers grown in a night air temperature of 80° F. were larger than a similar series grown at a temperature of 60° F., but the relative differences between the plants in the various containers in the same series remained the same. Furthermore, the soil temperature in the paper pot was more like that of the glass containers, yet plants in the glass containers were frequently better than those in clay pots and the plants in the paper pots were poorer than those in the clay pots. These results indicate that the soil-temperature factor is as unimportant as the porosity factor so far as it applies to growth in paper pots.

The habit of growth in the paraffined paper pots was quite similar to growth obtained when a nutrient deficiency exists. The leaves of the plant turned to a yellow green and became stiff. New leaves grew slowly and remained small. These plants resembled plants that have been exposed to very cool temperatures or have been put on a ration of a reduced quantity of water. These practices, i. e., cool temperature and little water, are used in the method of "hardening-off" plants either to hold them back in growth or to prepare them for the more rigorous life of field culture. However, the root system was very much unlike the strong root systems of plants that have been hardened-off. The ball of roots with soil was not present. The roots were very few and showed little tendency to branch. This absence of a fibrous root system on the outside of the soil mass was not due to lack of moisture on the outside of the potted soil. The paper pot soon became quite moist and in many cases was penetrated by roots that were working downward on the outside of the pot. Numbers 11 and 12 in Figure 1 show the poor root systems of plants grown in plain paper and paraffined paper pots. Numbers 16 and 17 are plants grown in clay and glass containers, showing excellent root systems.

Fig. 1.—Calendula Plants, 40 days in 4-inch containers.

No. 11, plain paper pot; 12, paraffined paper pot; 13, 14, 15, Bakelite varnishes on paper pots; 16, clay; 17, pint size glass fruit jar.

The leaves of the plants were strikingly similar to leaves on plants suffering from a lack of available nitrogen. Tomato plants in clay and paper pots were given an application of an ammonium sulfate solution (1 ounce to 1 gallon) when the plants in the paper pots had apparently stopped growing.

Check pots of both clay and paper were left untreated. Three days after this application the plants in the treated paper pots showed a darker green color and were soon quite superior to the plants in the paper pots to which no ammonium sulfate had been added. The plants in the clay pots which received ammonium sulfate showed a trace of improvement over the untreated pots, but the difference was marked only by darker green foliage. In Table 4 is shown the height of the plants, thirty days after the application of the ammonium sulfate solution.

TABLE 4.—HEIGHT OF TOMATO PLANTS IN FOUR-INCH PAPER AND CLAY FLOWER POTS, THIRTY DAYS AFTER AN APPLICATION OF AMMONIUM SULFATE SOLUTION

	PAPER POTS		CLAY POTS	
	Ammonium sulfate series	Check series	Ammonium sulfate series	Check series
	Inches	*Inches*	*Inches*	*Inches*
	22	13	23	22
	22	13	26	28
	24	14	26	25
	25	11	26	23
	22	15	18	25
Average	**23**	**13**	**24**	**25**

On the same day that the plants were measured, they were photographed (Figure 2).

Fig. 2.—Nitrogen Deficiency in Paper Pots.

Ammonium sulfate solution applied to pots marked N, two weeks after seedlings were set. Photographed 30 days after nitrogen was applied.

The nitrogen applied to the paper pots, even after the plants were checked in growth, was sufficient to bring the plants to a height practically equal to that of the plants in clay pots. That there was sufficient nitrogen in the soil when the seedling tomatoes were potted is shown by the fact that the clay pots receiving the ammonium sulfate solution produced no better plants than were obtained in clay pots to which no nitrogen had been added.

In practically every case the loss of green color by the foliage of the plants in paper pots was preceded by a softening of the pot, indicating that decomposition of the pot had started. Heavier coatings of paraffin prolonged the stiffness of the pot, thereby insuring good growth of the plants for a longer period than was possible in the paper pots protected with a light coating of paraffin. That the decomposition of the paper fibers is indirectly the cause of the nitrogen deficiency is substantiated by the results of many investigators who have studied the effect of decomposing cellulose on plant growth. This investigation, in its latter phase, indicates that when the paper fibers are so well protected that decomposition is impossible, no nitrogen deficiency will occur. The direct cause of the shortage of available nitrogen is the superior ability of the soil micro-organisms, producing the decomposition, to assimilate the nitrogen of the soil in competition with the plant.

In this case, the mass of soil was practically surrounded by decomposable cellulose. The literature on the effect of decomposing cellulose on plant growth is concerned with cellulose incorporated in the soil. However, as the paper soon becomes water-soaked and evaporates water from its outside surface, the cellulose truly becomes a constituent of the soil, and it is not improbable that the same or similar processes of cellulose decomposition are involved. It must also be kept in mind that when decomposition of the pot has reached the point where the pot becomes water-soaked, this area acts as an evaporating surface and there would be a movement of the soil solution to this area. Furthermore, the feeding roots are close to the inside surface of the pot, the very region where microbial activity is the highest and where there would be the greatest competition for nutrients of the soil.

The recent work of Collison and Conn (2) confirms the explanation of earlier investigators, i. e., "that the presence of highly carbonaceous material stimulates the activities of micro-organisms which compete with the plants for the available nitrogen and in that way cause a nitrogen shortage in the medium." Of these investigators may be mentioned Krüger and Schneidewind (10) (11) who first proposed the theory. Pfeiffer and Lemmermann (13) decided that the micro-organisms used the nitrogen as a necessary food for their existence. Kellerman and Wright (8) came to a similar conclusion when they created a state of malnutrition in citrous seedlings by addition of cellulose to the soil. Hill (6) studied the length of time that cellulose depressed the nitrate content of a soil. Doryland (4) and Rahn (14) concluded that the supply of soil nitrogen may be utilized by the micro-organisms to the extent that it may become a limiting factor to their activities. Allison (1) makes an application of the nitrogen-carbon ratio which has the approximate constant of 1:10 in humid regions. When this ratio is widened by the introduction of a highly carbonaceous substance there is an increased activity of micro-organisms to narrow the new ratio in the process of which the relatively small amount of nitrogen is tied up in the protein substance of the organisms. This nitrogen may be utilized over and over again by these organ-

isms and is not available for plants until the ratio approaches the 1:10 constant.

The work of Viljoen and Fred (15) in which wood and wood pulp cellulose were used shows a harmful effect on plants. These investigators agree that the harmful effect was due to the need for nitrogen by the organisms decomposing the cellulose. As the paper pots are of this form of cellulose, there is no doubt that the same processes were taking place.

Knott and Jeffries (9)[3] also working with paper flower pots made actual determinations of nitrate present in the soil. Their data show that in the process of decomposing the cellulose, the nitrate nitrogen of the soil had been reduced six-sevenths. Their recommendation that the effect of nitrate deficiency may be overcome by periodic applications of a nitrate solution is in agreement with the data of Table 4 in this paper.

Knott and Jeffries (9) recommend the treating of paper bands or pots with wax, asphalt, or other chemicals. The rate of decomposition will then be reduced and there will be less danger of nitrate starvation.

The effect of a nitrogen deficiency can be overcome by applications of available nitrogen. It was the purpose of the writer, however, not to remedy the effect, but to remove the cause. It was reasoned that a paper pot in which the fibers are so well protected that decomposition can not occur should grow as good plants as those grown in glass containers.

Many different materials were used[4], some of which gave a partial degree of protection. Substances, which usually protect wood and are subjected to wide fluctuations of temperature and moisture, could not withstand the inroads of the weathering processes taking place in the humid atmosphere of the soil, a soil with a slight acid reaction, and replete with biochemical processes set up by the micro-organisms of the soil.

Inasmuch as any water-proofing material would decrease the porosity of the paper pot, the trend of pot composition would be to approach a structure that resembled glass. Hence, in all tests, glass containers as well as clay flower pots were used as checks. If glass produced poorer plants than those grown in clay pots, the practicability of the results would be doubtful.

The materials used for water-proofing were given careful consideration. Combinations of treatments were made, including inside and outside surfaces and treatments before and after the pots were formed. Special grades of paraffin, sodium silicate, lacquer, varnish, Bakelite varnish, cellophane, and asphalt were used. Pots were provided with plant nutrients and also chemicals toxic to organisms (mercuric chloride and copper sulfate) incorporated in the paper before the coatings were applied.

Tomato and calendula seedlings were used as indicator plants as they grow fairly rapidly and the leaves quickly turn yellow when a nitrogen deficiency exists. As the testing progressed and many of the treatments to the paper were eliminated, the final test was carried out with geranium plants in four-inch pots. The geranium grows slowly and did not become pot-bound

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[3] The program of testing paper pots with various water-proofing materials was well advanced before the publication of the good work done by Knott and Jeffries.

[4] The writer is indebted to Mr. E. L. Connolly of Bird & Son for the treated paper pots and to the Bakelite Corporation for furnishing this laboratory with three Bakelite varnishes.

in the course of the five-month period when this test of durability of the pots was under way.

When the fibers of the pot were properly water-proofed with a substance that had some degree of permanence, it was found that as good plants could be grown in the paper pots as in the glass containers; and the latter in turn were frequently superior to plants grown in the standard clay pots. The results of such a test are shown in Figure 1.

The Bakelite-treated paper gave excellent results as measured in growth. This substance is not adaptable to the machinery used in treating this particular paper, but it served to demonstrate the improvement obtained in paper pots when the fibers are properly protected from decomposing organisms.

It was further learned that a properly coated paper disc in the bottom of a paper pot improved the growth of plants. These discs serve to prevent the roots from passing through the cracks in the base of the pot. These cracks result from the folding of certain parts in forming the bottom of the pot. Of the 10 best growing pots in a series of 40, 3 were of glass, 5 were of paper with double coatings of varnish or lacquer and with discs, 1 was of paper coated with Bakelite, and 1 of paper with a double coating of lacquer. It is possible that the discs, by making a more solid bottom, prevent the leaching out of certain nutrients, particularly nitrogen. If the paper pots are set on beds of soil, sand, or cinders, these discs prevent the penetration of the roots into such a moist medium. If the discs are not present, the pots must be lifted frequently to break off these roots, otherwise the major part of the root system will get into the moist bench and be lost when the plant is moved to a new location.

The most practical paper pot was one in which the fibers were impregnated and bound together with asphalt. In subsequent tests with several different plants, this paper pot has proved capable of growing as good plants as are produced in clay pots. In Figure 3 are shown the results obtained with tomato, pepper, and calendula plants growing in three-inch pots of clay, paraffined paper, asphalt paper, and jelly glasses.

The asphalt paper pot may be profitably used by amateur plant growers who do not have greenhouse facilities. Commercial growers may find these pots of value for the last transplanting as the plants are then potted for shipping, thus eliminating the extra weight and breakage that would occur if clay pots were used.

Glass Containers as Flower Pots

The use of glass or vitreous materials in making flower pots, has a practical value. These containers promote good growth of plants in atmospheres of low humidity. In homes, offices, and arid areas of the country, such plant containers conserve the moisture in the soil, retain all the nutrients, and considerably reduce the time necessary for the care of plants.

The prevailing idea that flower pots must be porous is quite erroneous. In practically all laboratories, where plants are grown under controlled conditions, non-porous containers of metal or crockware are employed and no question has ever been raised that the lack of porosity of the container has vitiated the results of the experimental work. Unlike the porous pot, the glass container can not evaporate moisture on the outside surface. Unless care is exercised in watering, there is grave danger that the soil will be flooded by over-watering; but this may be guarded against by potting the plant with

Fig. 3.—Seedlings of Tomato (26 days), Pepper (39 days), and Calendula (43 days).

Left to right, 3-inch pots of clay, paraffined paper, asphalted paper, and jelly glasses.

sufficient soil so that very little volume is left above the surface of the soil that can be filled with water. In glass containers, soils that are wet to the touch need no water; if they are barely moist, water may be added. Though a drainage hole is not necessary, it may be helpful in case free water gathers in the soil. In a period of three months in a greenhouse, plants in glass containers required less than half as much water as those in clay pots. With house plants, the difference would be wider.

In Figures 1 and 3 are shown experiments with various types of pots; including glass. The glass containers in these photographs did not have drainage holes, yet glass produced plants as good as those grown in other containers, or better.

In order to demonstrate that glass containers were productive beyond the vegetative phase of the plant, an experiment was prolonged through the blossoming stage with calendulas. The plants were in 4-inch clay pots, 4-inch Bakelite-varnished paper pots, and pint glass fruit jars (holding the same volume of soil as a 4-inch pot). The plants in the fruit jars produced more flowers than those in any other type of container, as is shown in Table 5.

TABLE 5.—THE EFFECT OF THE TYPE OF PLANT CONTAINER ON THE PRODUCTION OF BLOOMS FROM CALENDULA PLANTS.

Type of pot	Pots	Blooms	Average blooms per pot
	Number	*Number*	*Number*
Bakelite paper	3	7	2.33
Clay	3	4	1.33
Pint glass jars	3	11	3.66

There are many forms of glassware that may be adapted to the growing of plants. Cheap glass tumblers and jelly glasses may be used for small plants. The ornate jardiniere may be better used as a plant container than as a means to hide a clay pot.

Rubber Flower Pots

In the course of the investigation, tests were conducted with a new type of flower pot made of rubber.[5] The saucer is attached, and a drainage hole enters the saucer from the side of the pot at the base. Careful tests indicated that the pots contained no substance harmful to the plants.

Some of the pots were coated with a Bakelite varnish; some with asphalt. The remaining pots were not coated, thus allowing the roots of the plant to come in direct contact with the rubber. All produced plants that compared favorably with plants in glass and clay pot containers.

Figure 4 illustrates the results in the rubber pots as compared with clay pots. Maidenhair fern was used as an indicator plant. The plants were grown in an office window and were practically equal when potted, 50 days before the photograph was made. At the time of photographing, the larger number of old and new fronds in the rubber pots indicated that the plants in these pots were the more thrifty. In Table 6 is given the count of old, new, and total fronds of each pot. The rubber pots are slightly flexible and the two in the photograph have been in use for over a year without any sign of deterioration.

[5] Manufactured by the Fisk Rubber Company, Chicopee Falls, Massachusetts.

Fig. 4.—Maidenhair Fern in Rubber and Clay Flower Pots.

TABLE 6.—LIVING FRONDS OF MAIDENHAIR FERNS, FIFTY DAYS IN CLAY AND RUBBER FLOWER POTS.

	Clay pots		Rubber pots	
	No. 1	No. 2	No. 1	No. 2
	Number	*Number*	*Number*	*Number*
Good fronds	24	23	56	31
New fronds	6	3	18	19
Total living fronds	30	26	74	50

Discussion

The type of pot, porous or non-porous, determines the method of culture to be used. The standard clay, porous flower pot, employed by the commercial grower, does not produce good plants in dwelling houses. In order to use this pot successfully, it must be kept on a bed of moist material so that the evaporated water may be replaced from outside the pot instead of from the moisture within the pot. Thus, a pot may be porous or vitreous without any injury occurring to the plant if cultural practices are adapted to the type of pot. The non-porous pot is adaptable to the requirements of house and office culture of ornamental plants, and may even be used by the commercial grower with special advantage if plants are to be shipped.

The porous pot may be made non-porous by filling the pores with paint, or similar preparations. The non-porous containers may be made of waterproofed fibers, glass, any vitreous material, or any synthetic substance that can be poured into a mould or stamped out, as metal. It should be kept in mind, however, that there should be no soluble chemical in the substance of the pot that will be harmful to plants. Should there be decomposable materials in the pot, nitrogen deficiency would probably occur.

Summary

An investigation has been made of the effect of flower pot composition on plant growth. Flower pots are either porous or non-porous. This character of porosity in any pot determines the cultural practice to be followed for good growth. The porous pot, because of its evaporating surface, allows the soil to dry out unless a means is provided for the pot itself to take up moisture from some outside source. The porous pot, when dry, can adsorb one-half the normal daily application of water given to 3, 4, 5, and 6-inch sizes, and one-third the amount given to a 7-inch pot. The evaporation of moisture from the outside surface of the pot has a cooling effect on the soil; but this cooling of the soil has no effect on plant growth. About twice as much water is lost from a porous pot by evaporation as from a non-porous pot in the same period of time.

The relative humidity of houses and offices is so low during the heating months of the year that the evaporating power of the air frequently dries out the lower half of the mass of soil in a clay or porous pot. The roots in this section, therefore, are killed, weakening the plant so that it gradually dies. The moisture deficit caused by the excessive evaporation is seldom made up by the daily watering of plants.

Paper pots, properly protected from the activities of micro-organisms, will produce as good growth as can be obtained in glass or clay pots. However, if decomposition is in progress, the organisms make use of the available nitrogen in the soil and the plant suffers from nitrogen starvation. This nitrogen deficiency may be overcome by the addition of available nitrogen to the soil in excess of what can be utilized by the micro-organisms.

The method of testing, with a variety of materials for water-proofing paper fibers, is described. Better growth was obtained by the use of a disc in the bottom of the paper pot used in the experiments. This disc served to prevent the leaching of nutrients and also aided in the retention of the root system within the pot.

The most practical paper pot was one in which the fibers were impregnated and bound together with asphalt. These paper pots produced plants equal to those grown in glass and clay pots.

Glass containers may be used successfully for plants. With a glass pot, or any non-porous pot, care must be taken not to over-water the soil. Compared with the watering of porous pots, the frequency for watering a non-porous pot may be cut in half. There should be more soil in a non-porous pot than in a porous pot to prevent excessive applications of water. Glass containers are particularly valuable for the home and office, or in atmospheres with a low humidity. They conserve the moisture, which is evenly distributed in the soil of the container.

Rubber flower pots represent a type of non-porous pot moulded from a synthetic substance. These pots produced good plants and are more permanent and less breakable than glass or clay pots.

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PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE.

5M-11-'31. No. 3952.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 278 December, 1931

Infectious Laryngotracheitis Carriers

By Charles S. Gibbs

The investigations on infectious laryngotracheitis for the past year at this Station have centered largely around carrier problems and control measures. While the goal has not yet been reached, important advances have been made, and the disease can now be handled under laboratory conditions more effectively than it was a year ago. The results contained in this paper are in no sense complete, but are published in the hope that poultrymen and others interested in the control of infectious laryngotracheitis may find in them some practical applications under field conditions.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

INFECTIOUS LARYNGOTRACHEITIS CARRIERS

By Charles S. Gibbs,

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Chronic carriers of the virus of infectious laryngotracheitis[1] were suspected at the beginning of this study, because cleaning and disinfecting the houses and moving apparently recovered birds to new quarters had failed to control the disease in more instances than could be accounted for by accidental infection. Moreover, on several poultry farms, the annual appearance of the disease among pullets and cockerels brought in from the range in the fall and mixed with older birds strongly indicated the presence of carriers among the adult birds. Then, in an examination of 144 birds by means of intratracheal swabs, two convalescent birds were observed (Gibbs, 1931) eliminating virus longer than usual while showing no symptoms of disease. Although these observations did not actually reveal the existence of chronic carriers, they signified the possibility of such, and the investigation was continued until the 14 chronic carriers described in this bulletin were found and studied.

Since these experiments on carriers of infectious laryngotracheitis were completed, Komarov and Beaudette (1931) report the finding of chronic carriers by the same method. While these investigators did not state the total number of birds examined, they concluded: "Finally, in a population of 25 birds which had infectious bronchitis 16 months previously, 3 carriers of the virus were determined."

For some time chronic carriers of infectious laryngotracheitis have been suspected. Now experimental evidence from two independent sources shows that such carriers actually exist.

Experiments on subjects closely related to chronic carriers, such as mechanical carriers, the channel of infection, the viability of the virus under natural conditions, and practical suggestions for the control of the disease are included in this bulletin.

Mechanical Carriers

Experiments have been conducted with sparrows and mice as possible carriers of infectious laryngotracheitis. Thus far the results indicate that these pests are not important in the transmission of the virus, as neither of them is susceptible to the disease. However, both sparrows and mice served as mechanical carriers when the feathers and hairs were smeared with fresh exudate from the tracheas of birds dying of acute infectious laryngotracheitis, a condition not likely to occur under natural circumstances. In another experiment two cages, one containing diseased birds, the other healthy birds, were placed twenty inches apart and connected with a wire runway, arranged so that only the sparrows and mice could pass from cage to cage, as shown in Figure 1. During the day the sparrows were seen passing back and forth in search of feed. At night the mice got

[1] This name was suggested by Dr. H. J. Stafseth, at the 1929 Conference of State and Federal Research Workers in Animal Diseases; and it has been recommended by the Special Committee on Poultry Diseases appointed to report at the 1931 meeting of the American Veterinary Medical Association. In order to assist the movement for standardized nomenclature in poultry diseases, the name infectious laryngotracheitis is, therefore, used in this bulletin for infectious trachitis and infectious bronchitis.

into the feed in both cages, clawing it over and picking out pieces to nibble. Since the susceptible chickens showed no signs of the disease, the mice and sparrows did not serve as mechanical carriers under these conditions.

Ten pigeons from two widely separated flocks were inoculated intratracheally with a virulent strain of the California infectious laryngotracheitis virus. The pigeons were not affected by the disease, although two pullets inoculated with the same virus at the same time died in five days. The virus lived only a few hours in the tracheas of the pigeons, for after one day tracheal exudates from them did not infect susceptible chickens. Beach (1931) was unable to reproduce the disease by inoculation in pigeons.

A goose sent to the diagnostic service, apparently suffering from infectious laryngotracheitis, was killed and necropsied. The gross and histopathological lesions indicated infectious laryngotracheitis, but four chickens inoculated intratracheally with fresh tracheal exudate failed to develop the disease, although they readily succumbed to a natural infection later. Graham and Thorp (1931) have reported a similar experience with a wild goose. As yet it is uncertain whether or not geese are susceptible to the disease or act as carriers of the virus.

An attempt was made to determine whether man could serve as a mechanical carrier of infectious laryngotracheitis. In this experiment 24 susceptible pullets and cockerels were placed in separate cages. The cages were set on three double-deck stands well isolated from one another. The birds on the first stand were numbered A1, A2, A3, A4, A5, A6, A7, and A8, respectively; those on the second stand, B1, B2, etc.; and those on the third stand, C1, C2, etc. A1 and B1 were inoculated intratracheally with a virulent strain of infectious laryngotracheitis, while C1 was kept as an uninoculated control. Six days after inoculation both A1 and B1 showed symptoms of infectious laryngotracheitis and were emitting tracheal exudate tinged with blood during paroxysms of coughing. Apparently the conditions were right for the next step in the experiment. Accordingly, the experimenter carefully washed his hands and arms in warm, 2 per cent compound cresol solution, finally rinsing in running tap water, and drying with paper towels. He then put on a recently laundered laboratory coat and handled the pullets and cockerels in the A cages as in a poultry judging contest, beginning with A1 and taking each bird consecutively. After disinfecting hands and arms and changing to another laboratory coat, he handled the birds in the B cages just as he had those in the A cages. The same procedure was repeated for the birds in the last group, beginning with C1. All of the pullets and cockerels in the A cages, five in the B cages, and none in the C cages came down with infectious laryngotracheitis within the period of incubation for this disease, indicating that man may serve as a mechanical carrier of the virus when the excretions are fresh and carried directly from sick to healthy susceptible birds. Later the controls (C birds) and B5, B7, and B8, which did not take the disease by handling, were inoculated intratracheally with virulent tracheal exudate from A2 and A3. B8 and all of the controls came down with infectious laryngotracheitis in due season and died. B5 and B7 did not contract the disease, and were later found to be resistant to it.

Acute Cases

The most important distributor in infectious laryngotracheitis, as in most acute infectious diseases, is the recently infected individual. The virus is nearly always found in the tracheal exudate during the acute stages, and it has been demonstrated in the internal organs in a limited number of cases in which an especially virulent virus was used and special laboratory methods employed.

The intravenous injections of filtered tracheal exudates into susceptible birds indicate that the living virus can circulate in the blood in sufficient quantities to cause general infections, but immune bodies are developed in this tissue, so that it has been impossible to demonstrate its presence by direct methods.

The nervous system is apparently rarely affected, although the hen shown in Figure 2 contracted the disease naturally and developed chorea from which it never fully recovered. The hen was kept under observation for six months. At necropsy a hemorrhage was found on the ventral surface of the cerebellum. A small blood vessel had ruptured in the cerebellar tissues and blood had flowed into the space between the meninges and the cerebellum, forming a clot. This rupture and blood clot appeared like those occasionally found in the respiratory, circulatory, and visceral organs of fowls dying of acute infectious laryngotracheitis. A slight infiltration in the brain tissues around the clot indicated that the blood was being slowly absorbed. In another set of experiments two hickens were successfully inoculated with infectious laryngotracheitis from the brain of a pullet dying of the disease. Blood clots were not found in this pullet, although the brain material was preserved by Swift's (1921) method and other chickens were inoculated later, confirming the infectiousness of the tissues examined.

Birds showing visible symptoms of infectious laryngotracheitis are called acute cases. (Figure 3.) An attempt has been made to determine the length of time acute cases eliminate virus, because of the importance of such knowledge in developing control measures. Since the experiments reported in this bulletin were started in November, 1930, individual tests have been made on 504 birds, with ten viruses from widely separated places in Massachusetts, four from California, and four from New Jersey. The number of cases of acute infectious laryngotracheitis among the birds studied, and the number of days during which they eliminated virus were as follows:

Virus Used	Resistant Birds	Acute Cases	Period of Eliminating Virus		
			Shortest	Longest	Average
	Number	*Number*	*Days*	*Days*	*Days*
Massachusetts strains	11	269	4	18	6.73
California strains	4	108	3	11	6.14
New Jersey strains	2	110	2.8	8	5.25
Totals and average	17	487			6.27

Chronic Carriers

Birds which show no visible symptoms of the disease and yet eliminate virus are called chronic carriers. The chronic carrier stage was not found at all ages, for 160 chickens, inoculated when two weeks old and younger, were included in these studies and when tested later no chronic carriers were found among them. Chronic carriers were found among the pullets, cockerels and older birds, as follows:

Virus	Chronic Carriers
Massachusetts strains	9
California strains	3
New Jersey strains	2
Total	14

The number of days the 14 chronic carriers eliminated sufficient virus at weekly tests to inoculate susceptible chickens, up to the date this paper was written, were as follows:

Carriers Number	Virus	Days
V 2270	Massachusetts	378*
V 2290	California	234
V 2320	Massachusetts	225
V 2321	New Jersey	211
V 2370	Massachusetts	252
V 2383	Massachusetts	200
V 8225	California	196
V 8277	New Jersey	154
V 1200	Massachusetts	182
V 1231	Massachusetts	140
V 1260	Massachusetts	165
V 1269	Massachusetts	98
J 3835	California	120
J 3393	Massachusetts	67

* V 2270 was still a chronic carrier at the time this paper was written.

The results of the above experiments indicate that a small number of all birds in a flock surviving infectious laryngotracheitis are liable to become chronic carriers for an indefinite period. The longest period was not determined, but the shortest was 67 days. The less virulent Massachusetts virus produced the greatest number of carriers and the most virulent New Jersey virus the least. It is evident that the more virulent strains produced the smaller number of chronic carriers. The reason for this is unknown, although it may be readily supposed that these strains killed some of the birds that would have become chronic carriers if they had been infected with a less virulent virus. When a bird once became a carrier it invariably remained so for two months or longer up to an indefinite period. Chronic carriers for shorter periods were not found in these experiments, although birds harboring the virus may have existed and not been detected by the laboratory methods used.

Two Types of Chronic Carriers

Two types of chronic carriers, characterized in this bulletin by the terms "regular" and "irregular," were found among the birds examined. The regular carriers eliminated the virus at weekly tests as long as they remained carriers, while the irregular carriers failed to eliminate virus at two or more tests during the carrier stage. Possibly the birds should have been classified as constant and intermittent carriers, but on account of the cost involved in providing chickens for making the tests it was impossible to study the constancy and the intermittency of the elimination of the virus more closely. The number of regular and irregular carriers as detected by weekly inoculations of tracheal exudates from the chronic carriers into the tracheas of susceptible chickens were as follows:

Virus	Carriers	
	Regular	Irregular
Massachusetts strains	7	2
California strains	2	1
New Jersey strains	2	0

Figure 1. Wire Cages Connected by Runway—used for the mouse and sparrow experiments.

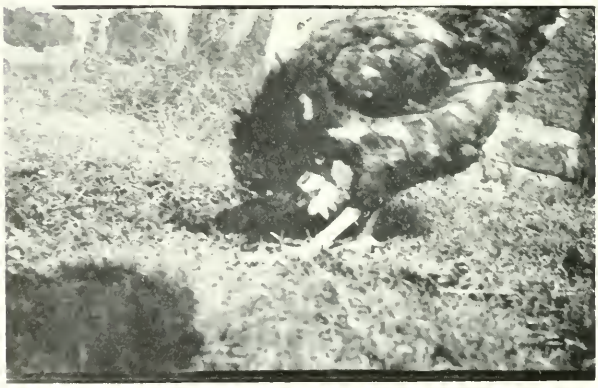

Figure 2. Chorea in a Fowl, following an attack of Infectious Laryngotracheitis.

Figure 3. An Acute Case of Infectious Laryngotracheitis.

As soon as the chronic carriers ceased to eliminate virus from the trachea, they were killed, and the internal organs were tested for the presence of virus by direct and indirect methods. The virus was not found in any of the internal organs examined; but it should be borne in mind that the total number of carriers was limited to 14, and that it is difficult to demonstrate the virus of infectious laryngotracheitis in the tissues of birds by laboratory methods, unless it is present in large quantities.

Experiments with Dried Infectious Laryngotracheitis Tissues and Exudates

The cages used in the experiments with man as a mechanical carrier were disinfected by submerging for 12 hours in a tank containing 3 per cent cresol solution, numbered, and returned to the stands. Twenty-four pullets and cockerels were placed in the cages. For a month the birds in the A cages were fed desiccated diseased tracheal tissues and exudates, but none of them developed the disease. At the end of the month the birds were inoculated, intratracheally, with tracheal exudate from a pullet dying of the disease and all were found to be susceptible.

The litter in the B cages was thoroughly dusted with some of the same material that was fed to the birds in the A cages, except that it was ground to a fine powder. All of these pullets and cockerels developed the disease in three to seven days after the first dusting, and six of them died.

The birds in the C cages were fed powdered infectious laryngotracheitis material in gelatine capsules, but did not take the disease. Later their tracheas were swabbed with powdered tissues and exudates and all of them developed the disease and died.

These laboratory investigations indicate that the virus is not likely to cause disease in susceptible pullets and cockerels unless it is in some form that will readily attach itself to the mucous membrane of the respiratory tract. In other words, the channel of infection in laryngotracheitis seems to be the respiratory tract, and it makes little difference whether the virus is moist or dry; for duplicate feeding experiments with moist tracheal tissues failed to infect susceptible chickens while the spraying of liquid exudates invariably produced the disease.

The Viability of Infectious Laryngotracheitis Virus Under Natural Conditions in a Poultry House

The preceding investigation indicated that the environment in some poultry houses might be conducive to the preservation and spread of infectious laryngotracheitis, especially in cold weather. An experiment was therefore planned to determine the viability of the virus under these conditions. In this experiment small pieces of epithelium, pseudomembrane, and tracheal exudate were scraped from the tracheas of fowls dying of the disease, and placed in serological test tubes which were plugged with cotton. Then the tubes were buried in the litter on the floor of the poultry house. Every day during the course of the experiment, except Saturday and Sunday, a tube was dug up and the contents examined and used to inoculate chickens susceptible to infectious laryngotracheitis.

The results of this experiment indicate that the virus was not preserved for any great length of time under the conditions in the litter of the poultry house, except during the latter part of January and the first part of February

when the temperature and relative humidity were comparatively low. The conditions then prevailing were more favorable, and the virus was preserved in a viable condition in one trial for six days and in another for nine days. All of the virulent pieces of tissues and exudates had dried out considerably, but not enough to preserve them indefinitely.

The location of the tubes in the litter and in the poultry house was important; for the virus in the tubes placed in moist and sunny places, such as near the drinking fountain and in front of the windows, lost its virulence in three days. The virus in tubes buried in the corners, under the roosts, and under the laying boxes remained virulent for longer periods.

It was impossible to measure the contribution of other factors that may have been involved in the partial desiccation and prolongation of the virulence of the tissues and exudates in the test tubes. Possibly the dry, dusty litter absorbed the moisture, and such aerobic bacteria and moulds as grow at low temperatures removed some of the oxygen, thus making the atmospheric conditions favorable for a partial preservation of the viruses used in these experiments.

Practical Applications

When infectious laryngotracheitis has existed in a flock and the recovered birds are kept for breeding purposes, there is reason to suspect that some of them may be carriers, and it is very unwise to mix any of the pullets and cockerels coming in from the range in the fall with the breeders. The two flocks should be kept entirely separate. The old hens and roosters should be disposed of as soon as the breeding season is over, and the premises which they have occupied thoroughly cleaned and disinfected. In this way the cycle of infection as it occurs on many poultry farms should be broken and the disease should disappear from the premises.

Terminal disinfection is important in poultry management and should receive more attention than is ordinarily given to it. Terminal disinfection has to do with cleaning up after an outbreak, or after disposing of birds among which carriers are suspected. Before disinfection can be intelligently appled something should be known about the virus, bacteria, or parasite it is desired to kill. It is already known that infectious laryngotracheitis is caused by a filtrable virus (Beach, 1930; Beaudette, 1930; Gibbs, 1931; Graham, Thorp and James, 1931). Experiments show that this virus is easy to destroy outside of the bird. Ordinarily it does not live longer than 24 hours at 68° F. (20° C.) when exposed to light and air, or 3 or 4 days when placed in an ice box. If moisture and air are removed by means of a vacuum pump, and the dehydrated virus is kept in a sealed desiccator just above the freezing point, its virulence is often maintained for several months; but these conditions are unusual, and seldom, if ever, found in a poultry house.

The virulence of the virus in tracheal exudates and possibly in other secretions from diseased birds may be prolonged in the litter of poultry houses in winter. While factors responsible for this prolongation are not well understood, it is quite likely that constant low temperature, low relative humidity, dry environment, and overcrowding are largely responsible for the spread of the disease in poultry houses.

With these facts in mind it is possible to understand why it is very difficult to control infectious laryngotracheitis in winter. At this time of year the virus is likely to be more resistant than it is at other seasons. The disinfectant is apt

to freeze and fail to reach all of the places intended. In addition, colds and roup are likely to appear as complicating factors due to increased draughts and dampness. Usually the best time to clean up after an outbreak of infectious laryngotracheitis is in the summer. All litter should first be removed from the house and burned. Then the house should be thoroughly washed with hot water and disinfected with one of the "Permitted Disinfectants."[2] The liquid should be sprayed with a force pump, or rubbed into all cracks with a good stiff broom. After standing for a week with doors and windows open to admit light and air, the premises should be free of infectious laryngotracheitis.

Summary

1. Sparrows and mice are not important mechanical carriers of infectious laryngotracheitis.

2. Ten pigeons inoculated intratracheally with virulent strains of infectious laryngotracheitis failed to contract the disease, or to carry the virus in their tracheas for any great length of time.

3. Man may serve as a mechanical carrier of the virus if he handles birds in the acute stages of the disease and directly picks up susceptible chickens, pullets, or cockerels.

4. Acute cases eliminate virus as long as they live, up to 10 or 15 days, or until they show no visible symptoms of the disease.

5. Fourteen chronic carriers out of 504 birds tested eliminated virus for indefinite periods.

6. The number of chronic carriers in a flock surviving an attack of infectious laryngotracheitis depends upon the size of the flock and the virulence of the virus.

7. If the birds used for breeding purposes have had infectious laryngotracheitis and the pullets and cockerels have remained free of it, the two flocks should be kept separate in order to break the cycle of infection and get rid of the disease.

8. The respiratory tract seems to be the most important channel of infection.

9. Usually the best time to clean up and disinfect after an outbreak of infectious laryngotracheitis is in the summer.

10. It should be borne in mind that the control measures suggested in this bulletin are based upon a laboratory study of infectious laryngotracheitis, and it is too much to expect that they will meet all situations arising in poultry practice without some adaptation or modification.

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[2] A list of the permitted disinfectants may be procured by application to the United States Department of Agriculture, Washington, D. C.

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Acknowledgments

In conclusion, the writer wishes to extend his sincere thanks to Dr. J. R. Beach of the University of California and to the Rockefeller Institute for Medical Research for contributing the California and New Jersey viruses of infectious laryngotracheitis used in this study.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE

4M-1-32 No. 4477

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 279 December, 1931

Onion Spraying and Dusting Experiments

By William L. Doran and Arthur I. Bourne

In 1927 and 1928 seed onions died prematurely in the Connecticut Valley of a disease here designated as blast. In earlier years downy mildew of onions, also, sometimes caused a reduction in yields. The experiments here described were undertaken with the object of learning to what extent fungicides will protect onions against these diseases.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

ONION SPRAYING AND DUSTING EXPERIMENTS[1]

By William L. Doran, Research Professor of Botany, and

Arthur I. Bourne, Research Professor of Entomology

Introduction

The field experiments here reported were conducted in 1929, 1930, and 1931, with the object of adding to the knowledge of the effects of Bordeaux mixture (4:4:50 and 8:4:50), milk of lime (4:50), and copper-lime dust on downy mildew of onion (caused by *Peronospora schleideni* Ung.), on the blast disease of onions, and on growth and yields of onions in the absence of these diseases.

Downy Mildew

Downy mildew of onion was general and severe here in 1924, 1925, and 1926. This disease was also reported as present in 1927 and 1928, although it caused little if any loss in those two years.

It has been recommended (2, 14, 6)[2] that onions be sprayed with Bordeaux mixture for protection against this disease. Such a recommendation is sometimes made with reservations, however, and these seem to be justified by the observation of Knott (10). Writing in 1930 of conditions in New York State, he made the statement that, although a few growers try spraying or dusting onions with a copper fungicide each year, no satisfactory control of downy mildew has thus been obtained.

The disease was, however, found to be preventable or controllable by a copper fungicide in experiments in other States and, presumably, under other conditions. Milbrath (13) has reported that Bordeaux mixture (with a sticker) and also copper-lime dust, showed some promise as tested against downy mildew of onion in California. Similarly, Bordeaux mixture (with a sticker) is reported[3] to have given good results in the control of the disease in Colorado; and Dykstra[4] has informed us that Bordeaux mixture (5:5:50), applied at intervals of 10 to 14 days, satisfactorily controlled downy mildew of onion in small-scale tests in Oregon.

Both Jones (9) and Whetzel (15) observed injury to onion leaves sprayed with Bordeaux mixture. That aspect of the matter is considered subsequently in the present paper; for, in the case of plant diseases such as downy mildew and blast of onion, which do not occur or do not measurably reduce yields (in Massachusetts) every year, the effects of fungicides on the crop in the absence of disease, as well as the cost of spraying, are of especial importance, since there is at present no way of forecasting the probable presence or absence of these diseases, and that would involve spraying every year if at all.

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[1] The onion industry in Massachusetts in confined principally to that part of the Connecticut Valley located in Hampshire and Franklin Counties, and the observations and results of experiments recorded in this paper are similarly limited geographically.

[2] Reference is made by number to "Literature Cited," p. 184.

[3] Plant Disease Reporter, Supplement 61 Diseases of vegetable and field crops in the United States in 1927.

[4] Letter of September 11, 1929, from T. P. Dykstra, Assistant Pathologist, Oregon Agr. Expt. Sta.

Blast

In 1927, 1928, and 1931, seed[5] onions died prematurely in the Connecticut Valley, although downy mildew was practically or entirely absent, and it was apparent that thrips (*Thrips tabaci* L.), a common cause of the early death of onion leaves, was not responsible. In each of these years, this disease or abnormal condition here designated as blast, first appeared in or about the third week of July when periods of rain were interrupted and followed by high temperatures, bright sunlight, and drying winds.

Macrosporium porri Ell., the pathogenicity of which to onions has been established by Angell (1), *Macrosporium parasiticum* Thum., and Botrytis sp. were often, but by no means always, present on blasting onions.

Onions dying from blast were often found to have pink and decaying roots, and *Phoma terrestris*, which according to Hansen (7) is the true causal agent of the pink-root disease of onions, was isolated by him from onions grown in Massachusetts, which died prematurely in a year of blast. The pink-root disease was, however, no less common in the Connecticut Valley on onions which did not blast, but which died prematurely from other causes, notably thrips and drouth.

These and other considerations indicate, in our opinion, a physiological rather than a parasitic cause of onion blast. The disease did not spread in the sense that plant diseases caused by fungi or bacteria usually spread, as from one part of a field to another; nor was there any apparent relation to differences in soil or topography, soil reaction or previous cropping systems. Whole fields of onions and all fields over a large area, having little if anything in common except climatic environment, began to blast on or about the same day.

While the fungi named, and others, may be contributing factors which hasten the death of blasting onions, our observations and those of other investigators lead us to believe that blast of onion, like tip-burn of potato, has its first cause in the atmospheric conditions indicated above. Lutman (12) has demonstrated that tip-burn of potato is due to too bright sunshine and too high temperatures, and under these same conditions, he observed tip-burn (incipient blast) of onions. Furthermore, onion plants subjected by Jones (8) to conditions of high relative humidity and of light of low intensity, followed by exposure to relatively dry air and to bright sunshine, developed the fading, withering, and dying leaves symptomatic of blast.

In the experiments of Lutman (11) tip-burn of potato was found to be preventable by spraying with Bordeaux mixture, and these experiments with onion were undertaken with the thought that spraying with Bordeaux mixture, or with milk of lime, might be similarly effective in protecting onions against blast. Milk of lime was included, although it is without the fungicidal properties of Bordeaux mixture, for in the experiments of Butler (4) the action of both milk of lime and Bordeaux mixture (4:4:50) on sprayed plants was found to be one of shade.

Methods and Costs

The sprayed plots and their checks were in triplicate and the dusted plots and their checks were in duplicate each year. The treatments of all plots, including materials used, numbers of applications, and intervals of time between applications are recorded in Tables 1, 2, and 3.

[5] Blast as observed by us was confined almost entirely to seed onions, i.e., onions grown from seed, as distinguished from set onions, i.e., onions grown from sets and harvested earlier.

Copper-lime dust[6] was applied between 6 and 8 a. m. by means of a hand duster.

Potash fish-oil soap was used as a sticker with the Bordeaux mixtures and with milk of lime at the rate of 3 or 4 pounds to 50 gallons. The sprays adhered well.

It was evident that neither milk of lime nor Bordeaux mixture, even with the addition of fish-oil soap, protected onions against thrips. All plots, including the checks, were therefore sprayed with nicotine sulfate 1:1000, with fish-oil soap 3 or 4 pounds in 50 gallons, as recommended by Bourne (3), often enough to prevent injury by these insects.

Sprays were applied between 6:30 and 9:30 a. m. The spraying, with the exception of the applications made July 30 and August 5 in 1929, was done with the power sprayer which Bourne (loc. cit.) has described. With this machine, spray materials were applied at a pressure of 100 to 150 pounds. This outfit was equipped with a spray boom by means of which 6 rows of onions (13 inches apart) were sprayed at one time.

It was necessary to use another power sprayer in 1929 on the two days named above. This involved carrying a hose from the sprayer through the field, and on these dates onions were sprayed by hand, but at a pressure of 200 pounds. This resulted in a much less uniform coverage and the expenditure of more gallons of spray per acre.

At the end of each season, onions were screened to remove those less than $1\frac{1}{4}$ inches in diameter. The yields per acre of onions above this size which were harvested from each plot each year are recorded in Tables 1, 2, and 3 for the years 1929, 1930, and 1931 respectively.

A thorough coverage of the plants, using the power sprayer described by Bourne (loc. cit.) required approximately 250 gallons of spray per acre for each application, as an average for the entire season. An acre could be sprayed with this outfit in approximately $1\frac{1}{2}$ hours. This figure represents the time spent in actual spraying and also makes allowance for the necessary refilling.

Estimates of cost of application are based on these figures. No estimates of depreciation of the spray outfit or other items of overhead were included, since these would vary according to the machinery used and could not be figured accurately on an acreage basis.

The cost of four applications of Bordeaux mixture 4:4:50, including labor and materials, was $19.40 per acre. This included two applications in which nicotine sulfate was added for the control of thrips. The cost of materials alone for the Bordeaux and fish-oil soap combination was $2.85 per acre for one application. The addition of nicotine sulfate increased the cost to $5.35 per acre.

On a similar basis, the total cost of six applications of 4:4:50 Bordeaux (including two in which nicotine was added) was $26.60 per acre.

The 8:4:50 Bordeaux was applied twice (including one application with nicotine) at a total cost of $12.50 per acre. For three applications in which nicotine was included once, the total cost was $17.50 per acre. The cost of materials alone for Bordeaux of this strength with fish-oil soap was $4.25 per acre for each application. The addition of nicotine sulfate raised this figure to $6.75 per acre.

Milk of lime was applied six times (including two applications with nicotine) at a total cost of $18.20 per acre.

In every case, potash fish-oil soap was added to the Bordeaux mixture and milk of lime to increase the adhesiveness of the spray and give more uniform

[6] Guaranteed to contain not less than 19% monohydrated copper sulfate and not over 81% inert ingredients.

coverage. This represented a cost of $1.05 per acre for each application.

The most expensive item in each combination was the nicotine sulfate which added approximately $2.50 per acre to the cost of each application. Since Bordeaux or lime alone, however, proved no deterrent for thrips, the addition of nicotine sulfate was necessary.

Results in 1929

The season of 1929 was very dry. Some drouth injury occurred, but neither blast nor downy mildew was observed in this season.

Eight applications of copper-lime dust applied at weekly intervals, beginning July 1, resulted in decreases in yields of from 23.6 to 30.2 per cent. Yields were decreased rather more by six applications of copper-lime dust applied weekly, beginning July 22. In the absence of disease and under the weather conditions prevailing in 1929, copper-lime dust as applied was injurious to onions.

Leaves were rather severely injured by Bordeaux mixture 1:4:50 and by Bordeaux mixture 8:4:50 applied twice by hand, as described above. Milk of lime similarly applied was not markedly injurious. This injury is attributed more to the over-spraying and uneven coverage than to Bordeaux mixture itself; for in the case of early applications and applications in the two following years, made at a pressure of 100 to 150 pounds with the field sprayer (3), no injury by Bordeaux mixture was observed.

With no disease present and with spray injury apparent, it is not surprising to note (see Table 1) that decreased yields resulted in all plots sprayed with Bordeaux mixture. Bordeaux mixture 4:4:50 applied eight times at intervals of two weeks, beginning July 1, or Bordeaux mixture 8:4:50 applied 5 times at intervals of two weeks, were most injurious, resulting in reductions in yield of from 26.0 to 34.7 per cent. The injury following six applications of Bordeaux mixture 4:4:50, made at weekly intervals, beginning July 22, was much less; the reductions in yields in this case were from 1.6 to 11.9 per cent.

In two plots sprayed with milk of lime, there were small increases (7.4 per cent) in yield, but in the third plot thus treated, a decrease in yield resulted.

It is evident from this that Bordeaux mixture applied by hand and at too high a pressure, injured onions, and that this injury, with diseases absent, more than offset any possible beneficial effect of spraying.

Results in 1930

Yields (see Table 2) were low in 1930, although in 1930 as in 1929, neither blast nor downy mildew was present.

Yields were neither increased nor decreased consistently and significantly by copper-lime dust applied four times or six times at weekly intervals.

Six applications of milk of lime at weekly intervals resulted in decreases in yields of 4.9 and 10.2 per cent in two plots and an increase of 3.9 per cent in the other plot. The mean yield in plots sprayed with milk of lime was decreased by 3.9 per cent.

The effect of Bordeaux mixture, while not uniform in all plots, was in general beneficial. Increases in mean yields resulted in all cases, with the largest increase, 19.5 per cent, in the plots sprayed six times with Bordeaux mixture 4:4:50 or twice with Bordeaux mixture 8:4:50. Smaller increases (14.3 per cent) in mean

TABLE 1.—YIELDS OF ONIONS IN 1929.

TREATMENTS				NUMBER OF 100 LB. SACKS PER ACRE				PERCENTAGE INCREASE OR DECREASE IN YIELD*			
Material	Number of applications	Date begun	Interval (weeks)	Series 1	Series 2	Series 3	Mean	Series 1	Series 2	Series 3	Mean
No treatment (check for sprayed plots)				258	202	250	237				
Bordeaux mixture 4:4:50	8	July 1	1	186	136	177	166	27.9	-32.7	29.2	-30.0
Bordeaux mixture 4:4:50	6	July 22	1	228	178	246	217	-11.6	-11.9	-1.6	-8.4
Bordeaux mixture 8:4:50	5	July 1	2	191	132	178	167	-26.0	-34.7	-28.8	-29.5
Bordeaux mixture 8:4:50	3	July 22	2	221	179	221	207	-14.3	11.4	-11.6	-12.6
Milk of lime 4:50	8	July 1	1	226	141	223	196	-12.4	-30.2	-10.8	-17.3
Milk of lime 4:50	6	July 22	1	277	217	206	233	+7.4	+7.4	17.6	-1.7
No treatment (check for dusted plots)				149	89		119				
Copper-lime dust	8	July 1	1	104	68		86	-30.2	-23.6		-27.7
Copper-lime dust	6	July 22	1	96	52		74	35.6	-41.6		-37.8

TABLE 2.—YIELDS OF ONIONS IN 1930.

No treatment (check for sprayed plots)				122	51	59	77				
Bordeaux mixture 4:4:50	6	July 14	1	132	92	51	92	+8.2	+80.4	-13.6	+19.5
Bordeaux mixture 4:4:50	4	July 28	1	138	74	53	88	+13.1	+45.1	10.2	+14.3
Bordeaux mixture 8:4:50	3	July 14	2	154	53	56	88	+26.2	+3.9	-5.1	+14.3
Bordeaux mixture 8:4:50	2	July 28	2	145	68	62	92	+18.8	+33.3	+5.1	+19.5
Milk of lime 4:50	6	July 14	1	116	53	53	74	-4.9	+3.9	-10.2	-3.9

No treatment (check for dusted plots)				221	255		238				
Copper-lime dust	6	July 14	1	249	253		251	+12.7	−0.8		+5.5
Copper-lime dust	4	July 28	1	249	227		238	+12.7	−11.0		0.0

TABLE 3.—YIELDS OF ONIONS IN 1931.

No treatment (check for sprayed plots)				164	97	97	119				
Bordeaux mixture 4:4:50	6	July 13	1	168	137	110	138	+2.4	+41.2	+13.4	+16.8
Bordeaux mixture 4:4:50	4	July 27	1	181	124	121	142	+10.4	+27.8	+24.7	+19.3
Bordeaux mixture 8:4:50	3	July 13	2	166	114	87	122	+1.2	+17.5	−10.3	+2.5
Bordeaux mixture 8:4:50	2	July 27	2	170	118	108	132	+3.7	+21.6	+11.3	+10.9
Milk of lime 4:50	6	July 13	1	170	102	126	133	+3.7	+5.2	+29.9	+11.8
No treatment (check for dusted plots)				139	127		133				
Copper-lime dust	6	July 13	1	108	76		92	−22.3	−40.2		−30.8
Copper-lime dust	4	July 27	1	119	111		115	−14.4	−12.6		−13.5

* An increase is indicated by the plus sign (+); a decrease by the minus sign (−).

yields resulted in the plots sprayed four times with Bordeaux mixture 4:4:50 or three times with Bordeaux mixture 8:4:50. In only one series of plots were decreased yields associated with these treatments.

It is evident from this that yields of onions may be increased somewhat by Bordeaux mixture applied uniformly and at not too high a pressure, even in years of no downy mildew and no blast. Such an effect is tentatively attributable to a direct stimulation or to protection against fungi which are usually of minor importance. Increases in yields were, however, too small on the whole to indicate that spraying would be a profitable practice with neither blast nor downy mildew present.

Results in 1931

There was no downy mildew in 1931, but blast was severe, appearing, as in 1927 and 1928, about the third week of July.

It was evident by the first of August that onions sprayed with Bordeaux mixture were blasting less and more slowly than were onions not so sprayed. But the appearance of blast, although delayed, was not entirely prevented by Bordeaux mixture, and the increases in yields following spraying with Bordeaux mixture were not large. Yields were, however, increased somewhat in all plots sprayed with Bordeaux mixture 4:4:50, and in all but one of the six plots sprayed with Bordeaux mixture 8:4:50.

Six applications of Bordeaux mixture 4:4:50 were followed by increases in yields of from 2.4 to 41.2 per cent, but the increase in the mean yield of the three plots (16.8 per cent) was no larger than that associated with the corresponding treatment in 1930, when there was no blast. The most consistent and, on the whole, the largest increases in yields (with a mean of 19.3 per cent) were in those plots sprayed four times with Bordeaux mixture 4:4:50, but even in this case, the increases in yields were not much more than those which followed a corresponding treatment in 1930 with blast absent.

Two applications of Bordeaux mixture 8:4:50 were of more benefit than three applications of this fungicide, but increases in yield resulting from the former were smaller in this year of blast than in the previous year when that disease was absent.

Our conclusion, on the basis of the results in 1931, is that increases in yields resulting from spraying with Bordeaux mixture in a year of blast were not sufficiently large and consistent to indicate that the practice would be profitable under present conditions.

Yields were increased 3.7 to 29.9 per cent in the plots sprayed with milk of lime. These increases in yield in the presence of blast were, on the whole, larger than in the two previous years when blast was absent; but increases were small in two out of three plots. Milk of lime, on the whole, was of less benefit in both 1930 and 1931 than Bordeaux mixture, indicating that at least part of the benefit of the Bordeaux mixture was probably due to its superior fungicidal properties.

As in previous years, copper-lime dust was of no benefit. The onset of blast was not measurably retarded by it, and yields were lower in all plots to which copper-lime dust was applied. The decreases in yields in dusted plots were larger following five than following three applications.

Discussion and Conclusions

The absence of downy mildew in 1929, 1930, and 1931 made it impossible, of course, to add to the knowledge concerning the efficacy and practicality of

spraying and dusting with copper fungicides, for the prevention of this disease. But downy mildew does not cause loss in Massachusetts often enough or seriously enough to warrant spraying onions every year, unless it can be shown that increased yields would much more than pay for the cost of spraying in years when there is no downy mildew, and especially in years when blast occurs. We are now in a position to comment further on the effects of copper fungicides on onions under the conditions indicated above.

Copper-lime dust as used, resulted in injury to onions sufficient to more than offset any possible fungicidal value. In no year was it of any real or consistent benefit, and in two years, including a year of blast, it was definitely injurious and much more injurious than the same number of applications of Bordeaux mixture. Yields of onions in a year of blast were increased by Bordeaux mixture, but not by copper-lime dust. In this response, blast of onions again showed some similarity to tip-burn of potato, for in the experiments of Butler (5) copper-lime dust was much inferior to Bordeaux mixture in reducing injury of potatoes due to tip-burn.

Onions were not injured by Bordeaux mixture 4:4:50 or even 8:4:50 applied with suitable machinery at a pressure of 100 to 150 pounds, although it was injurious when applied by hand and in too large amounts at a pressure of 200 pounds. With the object of reducing the total cost of applications, Bordeaux mixture 8:4:50 was applied only half as often as was Bordeaux mixture 4:4:50. In the absence of blast, yields were increased about as much by Bordeaux 8:4:50 applied at intervals of two weeks as by Bordeaux mixture 4:4:50 applied weekly, and at less cost. Neither treatment, however, gave significantly increased yields with enough consistency to prove that spraying onions with a copper fungicide would be a profitable operation in years of no blast and no downy mildew. In a year of blast (1931), yields were increased more by Bordeaux mixture 4:4:50 applied weekly than by Bordeaux mixture 8:4:50 applied at intervals of two weeks.

Bordeaux mixture of both concentrations delayed the onset of blast, as it is known to delay the appearance of tip-burn of potato. Four weekly applications of Bordeaux mixture 4:4:50, begun July 27, just before blast occurred, were followed by the largest and most consistent increases in yield, and this is the concentration and schedule preferred should a grower wish to attempt protection against blast by spraying. Blast occurred in only one year out of the three in which these experiments were conducted and the increases in yield which resulted from this treatment were not, in our opinion, great enough to warrant the recommendation that onions be sprayed every year for protection against blast.

Increases in yield following the use of milk of lime were even smaller, and Bordeaux mixture is certainly to be preferred to it. But in a year of blast, yields were increased a little by milk of lime, this increase (for the mean) being greater than in years of no blast.

It has been established (3) that, in spite of certain practical difficulties involved, onions may be successfully protected against thrips by spraying two or three times in a season with a nicotine sulfate-fish-oil soap combination. But a satisfactory power sprayer for such a crop is relatively expensive and onions have not often been sprayed in the past to prevent injury by thrips. Growers who, individually or jointly, find the ownership of a power sprayer feasible, and who spray onions for protection against thrips may, on the basis of the results of our experiments, expect some further increase in yield if Bordeaux mixture 4:4:50 is used with nicotine sulfate. But the data as presented above do not

indicate that the purchase and use of a power sprayer solely for the application of Bordeaux mixture to onions would be profitable in the average year in Massachusetts. Since Bordeaux mixture, nicotine sulfate, and fish-oil soap are compatible and since the cost of spraying is not materially increased (only $1.80 per acre per application) by the inclusion of Bordeaux mixture 4:4:50 in this combination, it is suggested that these materials be used when spraying to prevent injury to onions by thrips.

Summary

Onions were injured by copper-lime dust in two out of three years, and loss caused by blast was not lessened by this treatment.

Bordeaux mixtures 4:4:50 and 8:4:50 were not injurious to onions when applied with a suitable power sprayer and at a pressure of 100 to 150 pounds.

In the absence of downy mildew and blast, yields of onions were increased somewhat by spraying with Bordeaux mixture.

Milk of lime was less effective.

The onset of blast was delayed, but not prevented by Bordeaux mixture. In a year of blast, yields of onions were increased the most by four weekly applications of Bordeaux mixture 4:4:50.

Increases in yield resulting from this treatment were not large enough to justify spraying onions every year with a copper fungicide alone under Massachusetts conditions, since downy mildew and blast are not present here every year.

It is suggested, however, that growers spraying onions with nicotine sulfate for protection against thrips include Bordeaux mixture in the combination spray.

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Publication of this Document Approved by Commission on Administration and Finance

2500-1-32 No. 4476

COLLECTION

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 280 FEBRUARY, 1932

Annual Report

For the Fiscal Year Ending Nov. 30, 1931

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1931

INTRODUCTION

F. J. Sievers, Director

The present economic conditions which are making themselves felt in a general industrial depression and consequent financial retrenchment, together with the maturing of the provisions under the Purnell Act, have provided little encouragement for the expansion of the service of the Experiment Station. Instead, certain readjustments of a more or less drastic nature were deemed necessary in the research program under way, and therefore several projects on which work has been in progress for a considerable period are being temporarily discontinued and the results prepared for publication. In other cases, through special efforts in promoting closer cooperation between departments, it has been possible to provide for the continuation of investigations that would otherwise have been prematurely terminated with the entire loss of previously expended energy and funds. Provisions for closer cooperation are especially effective in our relations with the United States Department of Agriculture through several of its Bureaus. In evidence of this are the projects in tobacco disease investigations, cranberry culture and bog management problems, corn borer control service, pasture management demonstrations and trials, and forage crop investigations, in all of which the relationships between the two agencies in question have been so satisfactory that there remained little to be desired.

While these developments in our program may not have made for the anticipated expansion so urgently requested by the loyal supporters of the Station, they, nevertheless, indicate progress of a desirable type. It is not unreasonable that, because of the tremendous changes in our entire economic structure, there should be equivalent readjustment in those research activities intended to exert a beneficial influence on industry. Agricultural experiment stations, as a result of their findings, have without question had a pronounced part in that increased efficiency which is considered partially responsible for the lack of proper balance in our entire industrial scheme. For a nation to be supplied to the point of superabundance in practically all commodities, and yet to be confronted with the extreme sociological and economical problems facing its population today, is the best evidence that we have not learned how to capitalize on the economic advantages at our disposal. The real solution of this tremendous problem requires research with a well-planned program of subsequent education; and our experiment stations, as organized, may well consider that they have a responsibility in this field.

Certainly with the continued increase in the application of science to all industry, and especially to agriculture, there will be a consequent need for regulation of employment to offset the lesser demand for labor resulting from the greater efficiency in its producing power per unit of time. This should also express itself in a demand for a constructive and more wholesome program of recreation to furnish an outlet for the proper utilization of increasing amounts of spare time and unemployed energy, if we are to capitalize fully on the real profits from

industry. The trend in this direction is already indicated in the demands especially expressed to us for research in the fields of floriculture, golf course management, landscape gardening, and in the culture of ornamental plants. In floriculture, golf course management, and landscape gardening the Massachusetts Station has already made sufficient progress in its investigations to show not only that scientific methods have a place in these fields, but that the results found are worthy of practical introduction and therefore are appreciated. Since New England in general, and Massachusetts in particular, is favored because of natural beauty and is rapidly becoming recognized by tourists and summer vacationists as one of the playgrounds of America, it may not be inconsistent to extend increased consideration to a program of research wherein this asset can be capitalized for purposes of promoting the recreational and the aesthetic. At any rate we shall be confronted with an increasing demand for service in this field as time goes on.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

The Economic Worth to Growers of Different Varieties of Apples. (Lorian P. Jefferson). This project, begun at the request of the Pomology Department, should be completed in 1932. At least one member of the Pomology Department is of the opinion that such a study would be of greatest value if continued for ten years. It has, however, been increasingly difficult to get from the growers consecutive annual figures for their orchards. One or two of the orchardists who gave reports for the first years of the study, met with untoward events, and their orchards could not be included the following year. One or two others gave figures one year, but because of lack of interest, did not wish to give them thereafter. The number of orchards from which reports are now available is much smaller than at first.

Consumer Demand for Eggs. (Lorian P. Jefferson). The field work on this project has been completed and much of the tabulation. Some few sections of the report are in the first draft.

Changing Methods of Wholesale Distribution of Perishables. (Lorian P. Jefferson). It is the general opinion of dealers that the great factors in bringing current changes in the wholesale marketing of perishables are the traveling jobber and the chain store. The work done on this project has been thus far confined largely to a study of the place of the traveling jobber in the marketing of fruits and vegetables.

The traveling jobber has been known in some markets for 10 or 15 years, but in the main he is a newcomer. The business requires little capital, just enough to get possession of a truck and perhaps pay for the first load of produce. Two classes of these jobbers are found: (1) The one does a legitimate business, performing a real service to the retailer with whom he deals. He buys as good products as the retailer desires and distributes them regularly over a regular route. He is a reliable customer of the wholesaler. Occasionally he buys also from the producer. (2) The other buys on a glutted market or when he can see a chance to make a profit. In general neither the wholesaler nor the retailer likes him. The wholesaler will not extend credit to this class, and many of the retailers report that they do not buy from them.

The chain store apparently has had no easy path in distributing perishables, a line which was not handled until comparatively recently. Their stores were not fitted to house fruits and vegetables, nor had they buyers or clerks who were acquainted with these products. This has apparently meant loss in handling perishables, and it is reasonable that this should cause much concern among chain store officials.

The development of the terminal market is another factor in current market changes. Some attention has been given to the South Boston Market Terminal. Statistics have been secured regarding the volume of various products handled there since the opening in 1927. Other material is available for the further study of the influence of this market.

Analysis of Market Prices for Massachusetts Vegetables. (H. B. Rowe.) The price and supply series used as the basis for this study have been extended to cover a ten-year period. More complete and precise analysis of the data, along the lines previously reported, has made possible the measurement of certain important trends and seasonal tendencies, as well as approximate statements of the relationships between local vegetable prices and such important price determinants as local supply, shipped-in supply, price level and business activity.

Recreational and Forestry Uses of Land. (David Rozman). The field work in connection with this project has now been completed and the material is being prepared for publication.

This study analyzes the present condition of abandoned farm land areas in Massachusetts and makes recommendations for the policies to be pursued in bringing about a balanced program of land utilization in the Commonwealth.

Housing Conditions and Problems in Part-Time Farming. (David Rozman.) During last summer an investigation was made of housing conditions and problems in part-time farming in Massachusetts and other New England states. The results of this investigation, together with recommendations, were presented in a report for the President's Conference on Home Building and Home Ownership.

Factors Affecting the Price of Eggs. (A. H. Lindsey). The small amount of time allowed for this project was expended on increasing the accuracy of outlook reports. Correlation between prices of eggs and meat prices indicates very little relationship. Storage margins have very little effect on the amount of eggs stored the following year.

The Relation of Quality Factors to Price of Eggs. (A. H. Lindsey). Work on this project is now completed and it is in manuscript form. The tabular analysis has been made during the last year with the following results:

Weight, as in the correlation analysis, varied directly as the price; quality varied with price through most price ranges, but premium prices did not insure best quality; the average quality of eastern eggs was invariably better than the average quality of western eggs. Price of storage eggs showed very little relationship to quality, but weight was directly related to price. The fact that eggs were branded or labeled did not guarantee uniform quality.

Correlations were run between the external factors, as number of dirty eggs, uniformity of color, uniformity of size, and price. The range in weight of eggs within the dozen had no apparent influence on price. The number of eggs off color reduced the price per dozen from ¼ to ½ cent per off-color egg. The reduction in price per dozen for each dirty egg was about ½ cent.

Competitive Factors Influencing the Supply of Market Milk and Cream. (A. H. Lindsey). Lack of time prevented additional work on this project, except for a survey of the Springfield milk market.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness). The study of apple storage carried on in cooperation with the Department of Pomology indicates that McIntosh apples can be stored at a temperature somewhat higher than 32° for a short time after harvest, if they are subsequently cooled to 32° for the balance of the storage season. A system of management whereby apples are kept at a temperature ranging from 40° to 45° during the first week after picking, with the temperature gradually reduced to 32° by the middle of October, results in no appreciable shortening of the safe storage season. This management permits a considerable saving in the cooling equipment required.

A study of the use of blowers as compared with wall coils indicated no tendency for the air blast to dry out the fruit during the 1930-31 season. This study is being continued during the present storage season.

In order to study the effect of humidity on the storage of apples, three cabinets were installed this season in three storage rooms maintained at different temperatures. Each of the cabinets has three chambers in which apples are stored. One chamber in each cabinet is maintained at a relative humidity of 65 per cent, one at 75 per cent, and one at 90 per cent. It is too early to comment on the outcome of this study.

Fertilizer Distributors. (C. I. Gunness). A device has been perfected for applying liquid fertilizers to golf greens or lawns where water under pressure is available. By this arrangement a relatively heavy application of fertilizer can be made without danger of burning, as the fertilizer solution is diluted by the water spray and evenly distributed.

Test of Low-lift Pumps. (C. I. Gunness). Two pumps were tested at the Cranberry Station at East Wareham during the summer. The tests indicate that where electric power is used, the self-contained pumping unit has a higher efficiency than can be obtained through the use of the large low-speed pumps which are commonly used on cranberry bogs.

DEPARTMENT OF AGRONOMY

A. B. Beaumont in Charge

Pasture Experiments. (A. B. Beaumont and E. F. Gaskill). The top-dressing of certain areas on the Tillson and Hobart farms and on ten farms in Worcester County was continued in 1931 with results quite similar to those of preceding years. Considerable evidence has now been accumulated which shows that run-out upland pastures of Massachusetts are deficient in calcium, phosphorus, potassium, and nitrogen.

Further evidence was obtained of the toxicity of nitrate of soda for a moss (*Polytrichum commune*), common to run-out, upland pastures of New England. Both the Chilean and the synthetic nitrate of soda exerted this toxicity, but it was not shown by several other commonly used nitrogen fertilizers.

Additional evidence of the superior palatability of timothy as a pasutre grass was secured. Holstein cows did not discriminate between timothy, Kentucky blue grass and redtop in the early stages of growth; but from the time the grasses were four inches or more high, the preference was first, timothy; second, redtop; third, Kentucky blue grass.

In cooperation with the Department of Animal Husbandry, a test was made of the Jerusalem artichoke as a midsummer and late summer pasture crop for dairy cattle. It was found that the crop furnished pasturage comparable in amount to that supplied by the temporary crops, oats, Sudan grass and Japanese millet. Most of the animals used in the experiment were slow in becoming accustomed to the new crop, though some ate it very readily.

Legume Variety Tests. (Wm. L. Jones and A. B. Beaumont in cooperation with E. A. Hollowell, Bureau of Plant Industry, U. S. D. A.).

Alfalfa. In the 1929 seeding, Argentine yielded the highest (4.92 tons in 2 cuttings), followed by Kansas, Hardigan, Nebraska, Ontario, Dakota Common, Disco, Utah, Italian, Hungary, Dakota 12, Arizona, South African, New Mexico, Ladak, Turkestan, Hairy Peruvian (3.20 tons). The field was covered with snow from the middle of December, 1930, till the first of March, 1931, which probably accounts for the good showing made by some of the southern strains. In the 1930 seeding, the yields were uniformly high, the order being: Dakota Common, Hardigan, Italian, South African, California, Ladak, New Mexico, Grimm, Hungarian, Argentine, Kansas, Oklahoma, Turkestan.

Red Clover. Eighteen American and European strains of red clover were tested. Owing to heavy August rains it was possible to make only one cutting, and that was fairly heavy for all strains. In general, American strains outyielded European strains and maintained the stand better through the season.

Vetch. Five varieties seeded in August, 1930, were so weedy in the spring of 1931 that it was not considered worth while to obtain yield data. Stand was best for Wooly Pod and Hairy, intermediate for Oregon Hairy and Oregon Common, and poorest for Hungarian. In the spring seeding of 1931, highest yield of hay was obtained from Oregon Pearl (1.44 tons per acre), followed in order by Hairy (15760), Oregon Common, Hungarian, and Smooth (15851) (1.04 tons). Experience thus far indicates that neither spring nor winter vetches are promising for this section.

Sweet Clover. In the experiment on date of seeding hulled (scarified) and unhulled sweet clover, best stands were obtained from seed sown in early December and January. In seedings made from February to May the stand decreased with advance of the seeding date, that is, the May seeding gave the poorest stand. There was no essential difference between the hulled and unhulled seed. All seedings were made on the surface of plowed and harrowed soil or on the snow covering.

Field Peas. Chang again yielded the most hay, followed in order by Golden Vine, Multiplier, Wisconsin Common, and O. A. C. 181; but owing to a bad infestation of aphids, the yield of each variety was less than 1 ton per acre.

Soy Beans. Of 20 varieties of soy beans, the following 10 yielded the most hay in decreasing order: Dunfield (3.01 tons), Chestnut, Habaro, Black Eyebrow, Medium Green, Harbinsoy, Pinpu, Mansoy, Soysota, Ito San (2.54 tons). Of these, Dunfield, Habaro, Medium Green, and Harbinsoy have been among the highest yielding 10 varieties for the past three years, Dunfield always leading.

Field Experiments with Onions. (M. E. Snell and A. B. Beaumont).

Fertilizer Ratios. Except for a few changes the fertilizer and lime experiments with onions were conducted as they were last year. One ton of lime per acre was applied to the south half of all plots, making possible a comparison between three 1-ton and one 2-ton applications over a period of seven years. Nine of the former cover-crop check plots, used last year for 6-8-8 plots, were changed over to 2-12-8 and 6-12-8 plots. (Figures refer to percentage of NH_3, P_2O_5, and K_2O.) The 4-12-8 organic gave appreciably higher yields this year, followed in order by the 4-12-4, 6-8-4, 4-7-4 (2-1-0 first top-dressing), 4-8-4 (nitrate top-dressing), and 8-16-8. The 2-12-8, 4-8-8, 6-8-8, and the 4-12-8 inorganic were all inferior to their adjacent checks. The three 1-ton applications of lime gave higher yields than one 2-ton application in almost every treatment. One ton of lime, applied to the plots of the old lime series which had had heavy applications in 1925, had a depressing effect on yield. Extra applications of superphosphate alone or with lime increased the yield, but of the two the lime seemed to be the more effective.

Size of Sets. Following the line of work started last year, a comparison was made of commercially graded sets ranging from ⅜ to ⅞ inch with specially graded sets ranging from ½ to ¾ inch, to determine whether the range in size of set could be broadened to include more sets without lowering their value for planting. It was found that the commercially graded sets produced a larger percentage of split bulbs and seed stalks as well as a greater variation in size of bulb. After all bulbs which were small, divided, or had seed stalks were deducted from both grades, it was found that the specially graded sets produced slightly more bags per acre than the commercially graded sets.

Growing Onion Sets. An experiment conducted last year showed quite conclusively that a medium-sized set was far more desirable for planting than either small or large sets. This made it desirable to know how to grow sets which would give a maximum number of the medium-sized sets. Accordingly an experiment was planned having two fertilizer levels, two widths of rows, and three rates of seeding. Best results were produced by 50 pounds of seed and 500 pounds of fertilizer per acre and 2-inch rows.

Onion Breeding. (M. E. Snell). This project has been developing gradually and expanding along the lines adopted at the beginning. Of the 80 strains and varieties tried, 36 have been discarded as inferior. The past season 992 bulbs which were selections from 142 of the better groups selected from the 1344 lots of bulbs grown in 1930, were planted for seed production. These bulbs represented 31 of the remaining 44 strains. Of the 142 groups planted for seed production, 13 were used in some crosses which were started this year. Vegetable parchment paper bags were very successfully used for covering the self fertilized heads in place of the cheesecloth coverings formerly used. The paper bags should be much more effective in preventing cross fertilization and seemed to give flowers and seeds better protection from unfavorable weather. The past season 284 lots of bulbs representing 14 of the original strains were produced from seed, 165 of them from self-fertilized seed and 118 from mass-fertilized seed. It has been observed that within groups there is a marked tendency toward uniformity of characters in the growing seedlings, the grown bulb, and the second-year plants. Some of the more outstanding characterisites are: color of leaves, coarseness of leaves, and early dormancy in the seedlings; firmness, shape, skin texture, and keeping quality in the bulbs; length of seed stalk, earliness of bloom, production of viable seed, and number of seed heads per bulb in the second-year growth.

Field Experiments with Tobacco. (A. B. Beaumont and M. E. Snell). Yields of tobacco in the field experiments were above average in 1931, but not quite so good as in 1930.

Cropping Systems. The highest yield (1816 pounds cured tobacco per acre) was obtained from plots which received a full ration (3500 lbs.) of commercial fertilizer (4.1%N, 4% P_2O_5, 5% K_2O) and had a cover crop of redtop the previous winter. Rye and timothy also, as cover crops, were beneficial but not to the same degree as redtop. Three-fourths ration of commercial fertilizer supplemented by 10 tons manure produced more tobacco than fertilizer alone, and about the same as a full ration of fertilizer with cover crops. A cover crop of timothy had a slight depressing effect on the results from manure and fertilizer. Low yields of tobacco were again obtained in the animal husbandry rotation (corn, timothy or clover, and tobacco). The yield of tobacco in this rotation was somewhat better after clover than after timothy, but following both crops only about two-thirds that of tobacco grown in continuous culture.

Different Quantities of Nitrogen. The highest yield (2025 lbs.) was obtained with 205.6 pounds nitrogen per acre, followed by 1953 pounds tobacco from 164.5 pounds nitrogen, 1727 from 123.4 and 1513 from 61.7. These figures are more in accordance with the mean of the past several years than were those of last year.

Different Carriers of Nitrogen. Where tobacco was preceded by timothy sod two years ago, the largest yield was obtained with ammonium sulfate, followed by sodium nitrate, cottonseed meal, and the standard mixture. Where timothy sod immediately preceded tobacco, the order of production was urea, ammonium sulfate, sodium nitrate, standard mixture, and cottonseed meal; but all these yields were only about three-fourths those from plots having corresponding treatments, but two years removed from timothy sod. Urea was introduced in this experiment for the first time this year and only on plots immediately following sod.

Method of Applying Fertilizer. A full ration applied in the row caused some stunting of plants, but in the end produced more tobacco (1996 lbs.) than the same amount applied broadcast (1906 lbs.); three-fourths ration in the row produced slightly less (1883 lbs.) than the full ration broadcast (1906 lbs.); and one-half ration in the row produced considerably less (1677 lbs.) than the full ration broadcast (1991 lbs.).

Miscellaneous. Milorganite, an organic fertilizer made from processed sewage, again proved a good substitute for cottonseed meal for tobacco, producing 1911 pounds cured tobacco. The quality of last year's crop from this material was slightly below that from cottonseed meal.

When ground tobacco stems were substituted for potassium salts as the carrier of potash in the standard fertilizer mixture, the yield of tobacco was 1459 pounds, while that from the standard mixture was 1689 pounds.

Nitrogen Metabolism in the Tobacco Plant. (W. S. Eisenmenger.) Tobacco plants grown in nutrient salt solutions were analyzed for total nitrogen and for the following nitrogen fractions: ammonia, nitrates, alpha amino acids, amides, water soluble albumen, proteose, and humin. Relatively large amounts of inorganic nitrogen were found in the plants. The plant parts arbitrarily chosen for analysis were roots, stems, midvein of leaves, and the residual part of leaf after midrib was removed. Although no categorical statement can be made as to the exact location of reduction of nitrate nitrogen in the plant, inferential evidence from the analyses would indicate that this process takes place at or near the midvein of the leaf.

Magnesium Requirements of Crops. (A. B. Beaumont and M. E. Snell) In a field experiment, corn, potatoes, timothy, alsike clover, soy beans, and onions were grown on soil known to be deficient in magnesium. Only corn showed distinct symptoms of magnesium deficiency by chlorosis of the leaves. There were some indications of chlorosis on soy beans and alsike clover, but they were not positive. However, with all crops except timothy, yields were better where magnesium sulfate was applied in recent years than where magnesium sulfate was not applied. Magnesium-deficient soils taken from the field in 1929 were used to grow corn, potatoes, timothy, alfalfa, red and alsike clover in pots. Here, also, only corn exhibited positive symptoms of magnesium deficiency.

Method of Applying Fertilizer to Corn. (A. B. Beaumont, E. F. Gaskill and R. W. Donaldson.) For the fourth consecutive year this test has been continued according to the standard plan prepared by the Joint Committee mentioned in the last annual report. Again it has been demonstrated that, under our conditions, a small amount of mixed fertilizer (4-10-6 grade) is more effective for corn when placed in the hill than when broadcast. Both the 125-pound and 250-pound applications in the hill produced more and better ears of corn than did 500 pounds broadcast. The exact placement of the fertilizer with reference to the seed made no difference so long as it was in the hill and near, but not in contact with, the seed.

Fertilizer Ratios for Grassland. (A. B. Beaumont and M. E. Snell). In 1928 an experiment in the top-dressing of an old mowing (meadow) was started. A mixed fertilizer with a varying ratio of nitrogen, phosphoric acid and potash has been used. Comparisons have been made by maintaining two of the nutrients at a constant level and varying the third. Data accumulated through four years show a distinct response to increments of nitrogen, a slight response to increments of potash, and no response to increments of phosphoric acid.

Nitrogen in Golf Green Clippings. (M. H. Cubbon). In 1928, clippings from greens in the vicinity of Amherst contained slightly less than 3 per cent nitrogen (dry matter basis) the first week in May. By the first of June the nitrogen content was 5 per cent. This general level was maintained until the latter part of August, with pronounced reduction after September 1. The highest individual percentage found was 5.92. Growing conditions were favorable throughout the season. No increase in nitrogen was found following application of nitrogen fertilizers.

Lawns and Lawn Grasses and Management. (L. S. Dickinson). Extensive studies have been made as to the desirability of pre-seeding fertilization of newly built lawns or other turf areas. The object of the studies was to obtain further data concerning the effect upon the balance between root growth and leaf of grasses when fertilizer is applied before seeding. Nitrogen, phosphorus, and potash were applied singly and in various combinations, and the grasses grown were Kentucky blue grass and Colonial bent. The results indicate that on normal soils pre-seeding fertilization with anything but superphosphate or a strictly phosphorus carrier is unnecessary and even undesirable if a well-balanced grass plant is desired. The project was made possible by the New England Greenkeepers' Association.

Additional data have been obtained regarding the influence of certain fertilizers and grasses on the control of angleworms in putting green turf.

The plots maintained in cooperation with the United States Golf Association continue to furnish interesting data, and the value of complete fertilizers with high nitrogen content is very obvious on the closely clipped putting green turf.

On the eight-year campus lawn plots with Kentucky blue grass, cottonseed meal continues to produce such a healthy stand of grass that weeds find no room.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Nitrogen Fixation in the Presence of or as a Result of Legumes versus Non-Legumes. (J. E. Fuller). Nitrogen fixation studies comparable with those previously published (L. A. Bradley and J. E. Fuller, Soil Sci. 30: 49-57, 1930) were made. Samples were taken from the various sections of the experimental plot in the spring (1931) before the crop was planted, and in the fall after the crop was harvested. Nitrogen fixation at both seasons appeared to be reasonably constant and generally distributed over the plot. There was no significant difference noted between the legume and non-legume strips. This agrees with findings of 1926 and 1928, reported in the publication mentioned above. In order to estimate the quantitative distribution of nitrogen-fixing microorganisms through the plot, studies were made of the various soil samples by a dilution method. The dilutions employed were 1 in 100, 1 in 1000, and 1 in 10,000, and 1-cc. quantities were inoculated in Ashby's solution. In soil samples taken in the spring there was no nitrogen fixation from any except the 1 in 100 dilution. The samples taken in the fall gave definite nitrogen fixation from all dilutions, indicating an increase in the number of the nitrogen-fixing microorganisms during the season. There was no difference between the legume and non-legume strips.

The activity of the soil in nitrifying dried blood and ammonium sulfate, and in decomposing cellulose, was studied. Both functions were active and generally distributed over the whole field. There was no difference between the legume and non-legume strips. These studies were made on the soils collected in the spring. Studies on the samples collected in the fall have not been completed.

The fertilizer treatment of the plot, and the crop planted on it, are reported under the same title as that above by the Department of Plant and Animal Chemistry (F. W. Morse).

Utilization of Mannite by Azotobacter. (J. E. Fuller.) The practice of reporting the amount of nitrogen fixed by bacteria as milligrams of nitrogen per gram of consumed mannite appears to be faulty. The mannite rarely is entirely consumed; and in 100 cc. quantities or less of culture media, it is impractical to estimate the amount of residual mannite. Experiments showed that soil inoculum and pure cultures of Azotobacter, each supplied with 10-gram quantities of mannite, fixed only slightly more than twice as much nitrogen as was fixed when 2-gram quantities of mannite were supplied.

Influence of Temperature on the Nitrate Content of Soil in the Presence of Decomposing Cellulose. (J. E. Fuller and L. H. Jones.) Compost soil with one per cent added cellulose (filter paper) was incubated for 6 weeks at temperatures of from 10° C. to 35° C., at intervals of two and three degrees. Nitrate tests were made each week. At temperatures of 25° to 35° there seemed to be sufficient nitrification to replace the nitrate loss in the presence

of cellulose. A nitrogen-poor soil with one per cent added cellulose (wheat straw) was treated in the same way as the compost soil. At all temperatures there was loss of nitrates in the presence of cellulose. Sodium nitrate, calcium carbonate, and calcium sulfate added to the soil separately and in combination at temperatures of 15° C., 25° C., and 35° C., did not prevent nitrate depletion in soil to which cellulose had been added. The loss of nitrate appeared to be greater when the calcium carbonate alone was added to the soil.

Laboratory Service. (Ralph L. France.) A total of 1,248 examinations was made in this laboratory during the past year. Briefly summarized they may be classified as follows:

Bacterial counts of milk	1,033
Sanitary analysis of water	149
Miscellaneous	66

Under miscellaneous are included examination of milk for garget or other abnormal udder conditions, examination of various food products for organisms causing spoilage, and chemical analysis of milk.

The total number of bacterial examinations of milk has increased materially over previous years. This is a clear indication not only that the laboratory is providing valuable service to the milk control program of the Valley, but also that dealers and producers now realize that a clean, wholesome product influences purchase by the consumer.

The total number of legume cultures distributed during the year has decreased considerably. In all probability this is due to the statewide distribution of cultures prepared by commercial concerns under the supervision and control of the United States Department of Agriculture.

The Indol Tolerance of the Colon-Aerogenes Group of Bacteria as a Possible Means of Differentiating Fecal and Non-Fecal Strains Occurring in Drinking-Water Supplies. (Ralph L. France.) The preliminary work on this project has been completed and the data are being assembled for publication. The results indicate that the methods for sanitary water analysis now employed in the majority of laboratories may lead to inaccurate interpretation of experimental results. Experimental evidence seems to indicate the necessity of submitting Colon bacilli found in water to various biochemical tests for the differentiation of fecal and non-fecal types of this organism rather than placing an interpretation of sanitary quality upon the routine Endo plate and lactose broth fermentation. A discrepancy of 40 per cent was found to exist between these two confirmation methods. The writer now proposes to submit these fecal and non-fecal strains of the Colon bacillus to various dilutions of indol in an effort to determine a possible difference in the indol tolerance of the organisms.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Tobacco Black Root-Rot. (W. L. Doran). Loss in yield of tobacco in plots last limed in 1923 is decreasing. The decrease in yield caused by black root-rot in these plots is now only about 16 per cent, or one-third of what it was in 1925. But the soil in these limed plots has not yet become any more acid.

An application of sulfur (500 pounds per acre) to a field, the soil of which had an initial pH of 6.4, lowered the pH value to 6.1, but this was insufficient to prevent infection of tobacco by Thielavia, and growth of plants was not affected. Yields of tobacco have been increased consistently when sulfur has been applied to a soil infested with Thielavia if the pH value of this soil was lowered by the sulfur to below 5.9, but not otherwise.

Liming was without any effect on the fire-holding capacity of the tobacco grown in 1929. In the case of the crop of 1930, the burn of the darks was improved, but the burn of the seconds was not affected by lime. Sulfur (400 pounds per acre) did not reduce the fire-holding capacity of the leaf grown in 1930. Burn of the darks was better in plots in which tobacco was grown every year than in plots in which tobacco followed timothy or alfalfa.

In 1930, the quality of tobacco grown in limed plots was as good as that in plots not limed. In earlier years, both yield and quality of tobacco have been lower in limed plots.

In pot experiments, soil pH values were not significantly lowered by aluminum phosphate alone, and they were lowered as much by sulfur alone as by sulfur with aluminum phosphate. When these treatments were applied to soil infested with *Thielavia basicola*, the severity of black root-rot was reduced and growth increased as much by sulfur alone as by sulfur and aluminum phosphate together.

Brown Root-Rot of Tobacco. (W. L. Doran). With the cooperation of H. D. Haskins, it was found that soils in which brown root-rot was most severe were characterized by high water-holding capacity, high content of clay and silt, and low content of sand. Soils in which brown root-rot was mild or from which it was absent, were characterized by high content of sand, low water-holding capacity, and low content of clay and silt. No consistent relation was found between the severity of brown root-rot and pH value of soil, soil content of organic and volatile matter, total nitrogen, nitrate nitrogen, or iron and aluminum oxides soluble in water.

The effects of ammonium thiocyanate on brown root-rot and growth of tobacco are being investigated.

Onion Diseases and the Use of Fungicides on Onions. (W. L. Doran). As in earlier years, this work was done in cooperation with A. I. Bourne. There was no downy mildew, but blast was severe in 1931, appearing, as in 1927 and 1928, about the third week of July.

The onset of blast was delayed, but not prevented, by spraying with Bordeaux mixture. Yields were increased somewhat, however, in all plots sprayed 4 times with Bordeaux mixture. As in the previous three years, copper-lime dust was of no benefit.

Growers who find the ownership of a power sprayer feasible, and who spray onions with nicotine sulfate for thrips, may, on the basis of the results of these experiments, expect some further increase in yield if Bordeaux mixture is used with nicotine sulfate; but there is no evidence that the purchase and use of a power sprayer solely for the application of Bordeaux mixture to onions would be profitable in the average year in Massachusetts.

A report of this work has been published in Bulletin 279.

Downy Mildew of Cucumbers. (W. L. Doran). In each of the six years ending in 1930, this disease has always occurred in Massachusetts; but it was not found in 1931, although many fields of cucumbers were examined at weekly

intervals until the plants were killed by frost. The occurrence of the disease here seems to have no relation to summer rainfall. Lack of primary infection rather than failure of the disease to spread would seem to explain its absence.

There is no positive evidence that the causal fungus, *Peronoplasmopara cubensis*, ever lives through the winter in Massachusetts. (It is usually present in greenhouses here in the fall and early winter, but has never been seen by the writer on the spring greenhouse crop.) This year, as in earlier years, oospores and other wintering-over stages were looked for, both in green leaves and in leaves killed by the disease and wintered in the soil outdoors, but none were found. As before, no infection resulted from the inoculation of cucumbers with inoculum consisting of cucumber leaves killed by downy mildew and buried in the soil in the field during the winter.

It has often been suggested that the fungus, wintering-over in Florida, may move northward with the crop and the advance of the season each spring and summer. In 1931, downy mildew was much less severe than usual south of here, notably so in Florida, Georgia, West Virginia, Delaware, and Connecticut. It was present as usual in Connecticut in 1930, but only a trace of it was found in that State in 1931, and that not until about two months after its usual date of appearance in the Connecticut Valley. There was, therefore, a minimum chance of the fungus reaching Massachusetts from states further south.

Acetic Acid and Pyroligneous Acid as Soil Disinfectants. (W. L. Doran). Damping-off was prevented, without injury to germination and with benefit to growth, by soil treatment with acetic acid 1.2 per cent, 2 quarts per square foot, 10 days before seeding. The cost, for a unit area of soil, was three-fourths that with formaldehyde. Damping-off was prevented, with no injury to germination, by vinegar 1 part diluted with 2½ parts of water (by volume) applied at the rate of 2 quarts per square foot 10 days before seeding. Seedlings of red pine were protected against damping-off, and germination was not injured, by acetic acid 0.8 per cent applied to soil at the rate of ¾ quarts per square foot at the time of seeding.

Pyroligneous acid, 4 parts diluted with water to a total of 100 parts (by volume), applied to soil at the rate of 2 quarts per square foot, protected seedlings against damping-off and did not injure seed germination even when applied to soil as late as 1 day before seeding. Per unit area of soil treated, the cost of pyroligneous acid was about 58 per cent of the cost of formaldehyde. The effect of pyroligneous acid on onion smut is now being investigated.

Eggplant Wilt. (E. F. Guba, Waltham). Study of the lower limit of tolerance of eggplant and its Verticillium pathogene to pH values has been continued. Inhibitory effect on growth of eggplant occurred from aluminum sulfate at pH 4.4-4.6, and from inoculated sulfur at pH 3.8-4.0. With aluminum sulfate there was good control of Verticillium at pH values between 4.5 and 5.0, but no control above pH 5.0; with inoculated sulfur there was some control at pH values between 3.8 and 4.8, but no control above pH 4.8. These results are in agreement with those offered in the previous report, and show that the lower limits of tolerance of eggplant and its Verticillium pathogene to pH values are too close to allow the practical use of sulfur or aluminum sulfate for obtaining the desired range of pH in which control, or partial control, of the disease could be expected.

In field experiments, an application of one ton of inoculated sulfur per acre lowered the reaction of the soil from pH 6.8 to 6.2. Aluminum sulfate at the same rate of application lowered the reaction to pH 6.4. No control of wilt was obtained

in either case. Other sulfur plots, continued from the previous season, gave satisfactory control of wilt and also retarded growth of the plants, indicating the difficulty attending artificial soil acidification. No further work on this project is contemplated.

Strawberry Gold Disease. (E. F. Guba, Waltham). Seed from strawberry plants affected with gold disease produced both diseased and disease-free seedlings, indicating seed transmission of the disease. Marked stunting and necrosis was associated with seedlings exhibiting this trouble. Experiments show that all the vegetative progeny of "gold" plants acquire the disease. Strawberry beds started with plants from beds free of gold disease remained free; but when new beds were propagated with plants free of the symptoms of the disease but from a source in which the disease was present, its prevalence in the new bed was not reduced. The selection of disease-free plants from a gold-disease source for starting new beds, with subsequent roguing of all plants showing symptoms of the trouble, failed to control the disease. Aside from the systemic nature of this disease, no evidence has been obtained to show the manner of spread.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham). *Tomato leaf-mold.* Efforts to control this disease by automatic adjustment of air conditions have been continued. In the fall-winter of 1930-31, 28.6 per cent less leaves infected with leaf-mold resulted with automatic humidity control (relative humidity 80-85 per cent and temperature 60°-73°F.), than with automatic temperature control (temperature 60°-65° F.), and the average total yield of tomatoes per plant with automatic humidity control was 1.09 pounds less than with automatic temperature control.

In the spring of 1931, operation of controls was discontinued after May 15 and thereafter all available ventilation was provided. Leaf-mold did not appear until June and eventually all foliage became infected, although the yield was not influenced. The total average yield of tomatoes per plant was 1.64 pounds less with automatic humidity control than with automatic temperature control.

A smaller amount of infected foliage and a lower yield have been associated with automatic humidity control, while under automatic temperature control and with careful management the prevalence of leaf-mold has never been great enough to reduce the yield. The reductions in yield associated with automatic humidity control appeared to be due indirectly to the higher temperatures needed to effect the desired control of the relative humidity of the greenhouse air.

A study of the relation of temperature to spore germination and growth of germ tubes is in progress.

A study of the reaction of a large number of tomato varieties to *Cladosporium fulvum* Cke. shows differences in the susceptibility. Further work is in progress to determine the feasibility of hybridizing desirable market types with types resistant to leaf-mold.

A manuscript dealing with the temperature and humidity relations of the causal organism and the relation of greenhouse air management to control of leaf-mold is being prepared.

Effect on plants of hydrocyanic acid gas after treatment with copper sprays. This work is being done in cooperation with Dr. E. B. Holland of the Chemistry Department.

Cucumber plants were never injured when fumigation with hydrocyanic acid gas followed spraying with Corona Copper Carbonate (18 per cent and 50 per cent active Cu) or Holland's Basic Copper Sulfate (26 per cent and 53 per

cent active Cu). These diluted sprays are neutral to litmus. On adding calcium hydroxide, injury followed gas and increased proportionately with the alkali present. Acid copper fungicides, i.e., normal and basic copper acetate, Bordeaux 1-0.20 and 1-0.22, Burgundy mixture 1:0.3 and caustic soda Bordeaux 1:0.2 followed by gas caused severe injury. Copper sulfate solutions .05 per cent and .07 per cent with gas were not injurious.

When gas followed spraying of cucumber plants with copper fungicides containing calcium hydroxide, sodium hydroxide, or sodium carbonate, injury always resulted. Even when the alkali component was reduced to make a mixture neutral to litmus, injury resulted after gas.

Injury occurred regardless of whether hydrocyanic acid gas was evolved from calcium cyanide or from sodium cyanide and sulfuric acid, and of whether chemical hydrated lime or milk of lime was used in the preparation of Bordeaux mixtures. The injured leaves always gave soluble copper, and the amount of copper and the degree of injury increased approximately with the alkali present in the fungicide.

Carbon bisulfide emulsion treatment for nematode-infested soil. Excellent results were obtained with both commercially prepared and homemade carbon bisulfide emulsions applied to nematode-infested soil. In bushel boxes, soil treated with the commercial product produced tomatoes with gall-free roots. In pots, a homemade emulsion gave clean roots in all but one instance. In both series of tests, the control plants were heavily infested. Repeated tests with homemade emulsion in badly infested commercial greenhouses gave satisfactory results.

Carnation Blight. (E. F. Guba, Waltham). A more complete list of varieties of carnations showing their reaction to the causal organism (*Alternaria dianthi* S. & Hall) has been prepared as a result of further study.

The optimum temperature for growth of the organism in pure culture is approximately 80° F.; the minimum and maximum limits are approximately 39° and 97° F., respectively.

Salt 5 per cent and nicotine sulfate 0.2 per cent, combined in solution and used for combating red spider, were not toxic to the conidia of Alternaria and did not in artificial inoculation experiments provide satisfactory protection against infection of potted plants. Salt solution possessed some fungicidal value, but nicotine sulfate none.

Potassium permanganate 1-1000 strength proved a valuable disinfectant for carnation cuttings. A 5-minute dip greatly improved rooting and provided rather good disinfection of Alternaria inoculum accompanying the cuttings.

Further experiments confirm the superiority of naphthalene fumigation in controlling Alternaria blight and Fusarium stem-rot as compared to water syringe. A difference of 35.1 per cent in yield of No. 1 blooms in favor of naphthalene fumigation was obtained.

Bordeaux 4-4-50 to which was added 1 pound of calcium arsenate, the same with the addition of ½ pint of fish oil, and Bordeaux 4-4-50 plus ½ pint of fish oil, were the most efficient treatments in the field, their relative efficiency being in the order given. A proprietary copper mixture, sulfur fungicides, and dusting materials containing sulfur, calcium arsenate, monohydrated copper sulfate, naphthalene, and lime gave no control of the disease.

Experiments show that outdoor planting, propagation before January, benching after July 10, and drip from leaks in the greenhouse greatly increase the hazard from Alternaria blight.

Monograph of the Genus Pestalotia. (E. F. Guba, Waltham). This interesting but taxonomically difficult group of fungi has been the subject of critical study for several years. Part I, published in 1929, embraced a study of 46 species of which 30 were found to be distinct. Part II, of which manuscript for publication is now complete, embraces a study of 52 described species of which 38 are distinct. A key to 68 species is appended.

In general the species are saprophytes or very weak parasites, capable of infecting their suscepts only through injuries. In the absence of biologic studies, no importance can be attached to published reports crediting species of Pestalotia as being true parasites.

Forcing Gladiolus with the Aid of Artificial Light. (L. H. Jones). Four greenhouse plots were planted with Crimson Glow gladiolus on September 6, 1930. The corms had been in cold storage since the previous March and germinated perfectly. They were planted 6 inches apart each way with a total of 70 corms in each plot. Two alternating plots were illuminated from twilight to dawn with 500-watt lights and were curtained off from the non-illuminated check plots. One check plot produced 3 spikes of blooms; the other check plot produced none. In the illuminated plots, 81 per cent and 69 per cent of the plants produced flowering spikes. The blooms in the check plot appeared three weeks before blooms in the lighted areas. The best spikes in any plot were the first to bloom. These occurred in the illuminated plots during the first 10 days of January.

Eradication of Nematodes in Greenhouse Soils by the Use of Chemicals. (L. H. Jones). Progress has been made in substituting the liquid orthodichlorobenzene for the dry paradichlorobenzene. By adsorbing the orthodichlorobenzene with diatomaceous earth, this chemical may be mixed with cyanogas and this mixture applied to the soil in a dry state. In preliminary tests, this mixture eradicated nematodes from a soil inoculated with large nematode galls. It appears that orthodichlorobenzene has the property of aiding the soil in the retention of hydrocyanic acid gas.

Plant Containers. (L. H. Jones). Non-porous containers made of paper, glass, rubber, or metal will grow plants equal to those grown in standard clay flower pots. Paper pots should have the fibers thoroughly impregnated and bound together with some waterproofing material to prevent decomposition of the container and consequent nitrogen deficiency in the soil. Non-porous containers lose soil moisture about half as fast as do clay pots. If a clay pot is kept on a dry surface, it develops an uneven distribution of soil moisture, the lower portion of the soil gradually becoming too dry for root action even though the upper layer is moist. This condition is caused by the excessive evaporation of soil moisture through the wall of the pot, for this loss of moisture is seldom made up by the daily watering of the plants. However, if the clay pot is kept on a moist surface, the evaporated water is replaced from without the pot and not from the soil moisture. The practice of employing a moist bench for clay flower pots, therefore, assures an even distribution of soil moisture. A non-porous container cannot evaporate moisture through the wall of the container, and, therefore, the moisture is conserved uniformly throughout the soil mass. A full report of this work is given in Bulletin 277.

The common belief that aeration of the soil takes place through the wall of the clay pot may possibly be true when the pot itself is dry; but if the pore spaces are filled with moisture, which is the usual condition in greenhouse prac-

tice, it is probable that the necessary aeration of the soil can occur only through the surface of the soil. It has been found in preliminary experiments that air under slight pressure passes through the wall of a dry flower pot very slowly, and yet this rate is thirty times as fast as the rate through a moist wall.

The reaction of the soil in regard to hydrogen ion concentration is not altered by conditions in non-porous containers any more than it is in clay flower pots. The soils in paper, glass and porous clay containers in which tomato plants had been growing for 40 days all reacted the same to tests for acidity. The reaction of soils in which geranium and petunia plants were grown for nearly four months in glass and metal containers without drainage holes, was no different from that of soil in the regulation clay flower pots. The reaction of the soil in paper pots was not affected by keeping the pots on moist beds of cinders, soil, or sand or on dry benches of wood and cement.

Influence of Light Quality on Plant Growth. (A. V. Osmun). In the experiment to test the effect of Vita glass on plant growth and development, the results were comparable with those of last year. Under Vita glass, radishes seeded January 14 and harvested March 17 averaged 11.3 per cent heavier than those grown under ordinary glass. Lettuce transplanted March 16 and harvested May 21, averaged 14.2 per cent lighter in weight under Vita glass than under ordinary glass. There was no appreciable difference in compactness of heads between the two lots of plants. At no time since the experiment was started in 1928, have differences been so marked as in the first tests, when the results were strikingly in favor of Vita glass. In every test but one with radish, Vita glass has given an increase in average weight of plants, while in only one test has lettuce averaged heavier when grown under Vita glass.

Plant Diseases Observed in 1931, Not Heretofore Reported in Massachusetts. (O. C. Boyd).

Wilt and black-rot of the following cucurbits caused by *Mycosphaerella citrullina* (C. O. Smith) Gross.; vine infection only of summer squash and muskmelon; fruit infection only of cucumber; both wilt and black-rot of winter squash, pumpkin, cushaw, and vegetable marrow.

Leaf-spot of winter squash, pumpkin, cushaw, vegetable marrow, and cucumber, caused by *Bacterium cucurbitae* Bryan (determination of organism by Mary K. Bryan, U. S. D. A.).

Leaf-spot of cucumber and muskmelon caused by *Septoria cucurbitacearum* Sacc.

Bacterial seedling blight of cucumber and summer squash (organism undetermined).

Wilt of okra caused by *Verticillium alboatrum* Reinke & Berth.

Leaf-spot of turnip caused by *Bacterium maculicolum* McC.

Leaf and pod-spot of pea (bacterial, undetermined).

Dwarf or crimps of strawberry caused by the nematode, *Aphelenchus fragariae* Ritzema-Bos. (determined by G. Steiner, U. S. D. A.).

"Stunt" or "die-out" of strawberry, suspected of being due to the virus of the true Yellows disease; observed only in Marshall berries.

Leaf-blight and rhizome-rot of iris caused by an unidentified bacterium.

Unusual Outbreaks of Previously Reported Diseases. (O. C. Boyd). Fusicladium scab of willows, rust and Gloeosporium leaf-blight of American ash, leaf-blotch of horse-chestnut, apple scab, peach bacterial-spot, brown-rot of

stone fruits, Macrosporium leaf-blight of carrots, black-rot of cauliflower, bacterial-wilt of cucurbits, onion "blast," Cytospora canker of blue spruce, hollyhock rust, bacterial-spot of delphinium, angular leaf-spot of cumcubers.

THE CRANBERRY STATION
(East Wareham, Massachusetts)
H. J. Franklin in Charge

The arrangement of 1930, whereby the extension services of Plymouth and Barnstable Counties maintained a service for the cranberry growers of the two counties, was continued during the most active part of the summer season of 1931 with very satisfactory results.

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin). Numerous special comparative spraying tests with the black-headed fireworm (*Rhopobota vacciniana*), in which nicotine sulfate and potash fish-oil soap, nicotine sulfate and potassium oleate soap, nicotine sulfate and penetrol, nicotine sulfate and lignin pitch-tannin mixture, pyrethrum extract, and pyrethrum soap were used, showed very clearly the marked superiority of a pyrethrum soap spray over all the other materials tried. Moreover, these tests brought out the fact that it pays to use 6 pounds of the commercial pyrethrum soap to 100 gallons of water instead of the 5 heretofore advocated. This amount of the soap was also found advisable in tests with the false blossom leafhopper (*Ophiola striatula*). The results obtained by many experienced growers in commercial practice during the season fully justified the results of these spraying experiments.

Tests with pyrethrum extract, pyrethrum soap, and nicotine sulfate and potash fish-oil soap against the red-striped fireworm (*Gelechia trialbamaculella*) confirmed previous results in showing that the nicotine sulfate spray is much the most efficient against this pest.

Tests showed that a pyrethrum soap spray (6 pounds in 100 gallons of water) is about as effective in killing moths of the cranberry girdler (*Crambus hortuellus*) as is the nicotine sulfate and soap spray (nicotine sulfate 1 qt., soap 4 lbs., water 100 gals.) commonly used to treat the black-headed fireworm.

In all the many tests made with it, pyrethrum extract was found so much inferior to pyrethrum soap in its toxic properties that its use seems seldom advisable for any cranberry pest.

Extensive dusting tests with various cranberry insects were carried out, the dust used being pyrethrum and a gypsum carrier of 300-mesh fineness. While these tests should probably be continued, the results obtained seemed to show plainly that such a dust is a satisfactory control for the false blossom leafhopper. It also killed the moths of the black-headed fireworm and so possibly may help as a control for that pest.

The general results of spraying with nicotine sulfate and soap to control the cranberry fruit worm (*Mineola vaccinii*) on various bogs were observed carefully and found to be not only encouraging but in some cases striking.

It is worth noting that the opinion is becoming pronounced among cranberry growers that the spread of the false blossom disease has been notably checked since treatments have been applied to control the leafhopper vector.

The life history of a species of *Tiphia* which is the main parasite of the cranberry root grub (*Amphicoma vulpina*) was largely worked out.

Cranberry Photosynthesis Studies. (H. J. Franklin in cooperation with the Bureau of Plant Industry, U. S. D. A.). This line of study was pursued very intensively during the summer seasons of 1930 and 1931 by Dr. William H. Sawyer of Bates College, given summer employment especially on this work, and Dr. H. F. Bergman of the Bureau. The results of their work are now being prepared for publication. A summary of their findings for 1930 and 1931 follows:

1. The climax of photosynthetic activity is reached by the middle of the forenoon (on a clear day), and the sugar content of leaves falls off after midday. This cycle of activity seems to be somewhat correlated with stomatal behavior, for in general there is a tendency for the stomata to close by noon, particularly if the temperature is high. It should be noted, however, that behavior of the stomata is exceedingly erratic, and the stomata do not all open or close at the same time, even in the same leaf.

2. The curve of sugar production in both the Early Black and the Howes varieties is subject to wide fluctuations on different days, even under apparently similar conditions of light and temperature. These fluctuations are in part correlated with the amount of sugar already present in the leaves; i.e., the gain in sugar is more rapid after a cloudy day when the sugar content is low than when the leaves start their photosynthetic activity with a sugar content already high.

3. Increase or decrease of reducing and total sugars usually, but not always, corresponds on a given day.

4. The percentage of reducing and total sugars in proportion to the weight of the leaves is consistently higher throughout the season in both young and old leaves in the Early Black than in the Howes variety.

5. An average of sugar production over several consecutive days indicates that, while the amount of sugar relative to the weight of the leaves is higher in the Early Black than in the Howes variety, the net amount produced over a given period does not differ appreciably in the two varieties.

6. Beginning with the middle of August there is a marked reduction in the amount of sugar present in both young and old leaves of both varieties. Moreover, it would appear that the withdrawal of sugar from the leaves, in comparison with its formation, is greater than earlier in the summer; and except under the most favorable conditions the withdrawal of sugar exceeds its formation.

7. The proportion of reducing sugars to total sugars in the leaves is less in the latter half of August than earlier in the season.

8. In mid-season starch is present in cranberry leaves in an amount roughly proportional to the maturity of the leaf. Little or no starch occurs in the rosette of young leaves at the top of the upright, but the amount increases progressively downward, including the old leaves. By the first of August, however, the starch stored in the old leaves begins to be withdrawn, leaving the upper layer of palisade cells first. Old leaves, by the time they turn yellow and fall, are devoid of starch.

9. During cloudy weather, or when the plants are kept in the dark, starch is removed first from young leaves near the top of the upright. A week in total darkness does not appreciably lower the starch content in the old leaves (leaves of the previous year's growth) in mid-June, but all starch is removed from leaves of the current season by such treatment.

10. In leaves of corresponding maturity there is usually more starch in those of the Early Black than in those of the Howes variety.

11. In stems, the starch in uprights is restricted to the pith; the starch in runners appears in the pith, wood rays, wood parenchyma, and outer cortex. The older portions of the stem contain most starch.

12. In the roots, starch occurs in the rays and the pericycle.

13. Oils begin to appear by the first of July in the most mature leaves of the current season as intracellular globules in the chlorenchyma, most abundant on the uppermost layer of palisade cells. These oil globules are also present in old leaves, even after they fall from the uprights. Oils in general are highly concentrated reserve foods, and in this case may help to promote new growth early in the season.

Weather Observations. (H. J. Franklin). Daily local weather observations were made and reported to the office of the Weather Bureau at Boston. Further records bearing on frost forecasting were made for the station by observers at North Harwich, East Gloucester, Carlisle, Fitchburg, Worcester, and Holliston, Massachusetts, and Storrs, Connecticut.

Pump Tests. (In cooperation with the Department of Agricultural Engineering). Several years ago Prof. C. I. Gunness tested the capacities and efficiencies of all the important bog pumps at that time in general use and published a paper on the work. This paper was well received by cranberry growers and by pump manufacturers. Since that time several new types of low-lift pumps have come into the field. As the demand was becoming urgent that these new pumps be tested, Prof. Gunness most generously undertook the work again, building a special testing plant at the Cranberry Station in 1930. He tested one pump in 1930 and completed the work during the summer of 1931, four pumps in all being tested, as follows: Fuller, Everson, Worthington, and Dayton and Dowd.

Cranberry Varieties. (H. J. Franklin). The study of varieties was pursued intensely during the early months of 1931. It was found that the species *Vaccinium macrocarpon* Ait., to which all the cultivated varieties of cranberries belong, comprises two important subspecies, and that wild hybrids between the two are very common. The Howes and McFarlin varieties were found to be such hybrids.

It was discovered that the ripe berries of most early and mid-season varieties do not have a noticeable bloom, while the fruit of most late varieties does. It has been supposed that the development of the wax of which this bloom is composed was useful to the plant as an adjustment to drouth, but the discovery mentioned suggests that with the cranberry it should rather be regarded as an adjustment to frost conditions.

Cultivated Blueberries. (H. J. Franklin). The first planting at the Cranberry Station blueberry patch was done in the fall of 1917 with about 300 untested seedlings furnished by the Bureau of Plant Industry. One of these seedlings has given an excellent account of itself and seems to be distinctly superior for commercial purposes in New England, all things considered, to any other variety so far produced. It should perhaps be patented. It has not yet been given a name but bears the culture number 1239W of the Bureau of Plant Industry. The particularly desirable features of this variety are:

1. Vigorous and plentiful wood growth.

2. Great productiveness. This bush seems to be considerably more productive than any other so far commonly grown.

3. Size of berries. The berries maintain a good size up to the very last picking in a way that those of no other variety do. While none of the berries

reach the size attained by the largest ones produced by some other varieties, the average size of all the berries is probably greater than that of any other variety.

4. Flavor of the berries. This is very good, though perhaps a bit too tart to satisfy some.

5. Keeping quality of the berries. The keeping and shipping qualities of the fruit appear to be as good as those of the berries of any variety, except possibly Pioneer and Rubel.

6. Picking quality. The berries pick easily and do not tear in picking. They cling to the bushes well and maintain a satisfactory condition while doing so, thus making frequent pickings unnecessary.

7. Cost of pruning. This is decidedly less than it is with some of the more important varieties under cultivation, especially Cabot and Pioneer.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Factors Affecting the Aging Time of Ice Cream Mixes. (K. E. Wright). One phase of the work—the adsorption of lecithin on the fat globule in ice cream—has been completed during the year and is about ready for publication. The following conclusions have been drawn:

1. It has been definitely shown that lecithin aids emulsification of an ice cream mix when incorporated under favorable conditions.

2. The high concentration of lecithin in buttermilk appears to be associated with the low surface tension of the latter. Therefore, lecithin would tend to concentrate at the interface of a fat-serum dispersion to act as an emulsifying agent.

3. Proof has been presented that lecithin functions better as an emulsifying agent when it is allowed to be directly adsorbed to the fat surface.

4. Cataphoretic measurements have failed to reflect any influence exerted by varying amounts of lecithin and so tend to indicate a fat-lecithin-protein system because protein influenced the behavior of the globules.

5. The reason for the failure of past attempts to improve whipping property of an ice cream mix has been attributed to a disturbance of the hydrophilic colloidal nature of lecithin.

6. The aging of an ice cream mix has been considered to be a process of adsorption of lecithin by the fat surface in which the amount of aging will tend to be in inverse relation to the amount of hydrophilic lecithin present.

The Utilization of Frozen Fruits in Ice Cream and Ices. (M. J. Mack in cooperation with the Department of Horticultural Manufactures). This project, which has included four different fruit crops, is nearing completion.

During the past year fruits, principally strawberries, have been frozen in syrups varying from 30 to 60 per cent sucrose, 80 per cent invert syrup, and in partial vacuum with either sugar or sugar syrups. These have been compared with the standard pack containing 2 to 3 pounds of fruit to 1 of cane sugar. These packs have been examined and then used in ice cream.

Fruit packed in 40 per cent syrup has been found to be the equivalent of, if not superior to, the standard sugar pack. Fruit frozen under partial vacuum has the advantage of no discoloration at the surface.

Fruit ice creams made from the above packs were found to be excellent. The ice cream maker should feel free to buy frozen fruits packed in either sugar

or sugar syrup (a 40 per cent syrup being most satisfactory), either plain or vacuum packed. Any of these methods are satisfactory for storing fruits for fruit ice cream. The condition of fruit when packed, and the variety, seem to be as important as the method of packing if the fruit is to be utilized in ice cream.

About 15 per cent of frozen fruit has been found to be desirable for flavoring strawberry, cherry, pineapple, banana, and other fruit ice creams. About 20 per cent is necessary for peach, and from 10 to 12 per cent for raspberry. The fruit should be added to the freezer immediately after the freezing process is started if a short freezing time is to be realized and the maximum of flavor is to be secured. No previous preparation of the fruit, as grinding or slicing, is necessary for the smaller fruits as the dasher of the freezer will break up the fruit. Fruit ice creams should be drawn from the freezer at about 23°F.

Frozen strawberries, raspberries, peaches, nectarines, plums, cranberries, and pineapples have been found to be as satsifactory as the fresh fruit for making ices or sherbets. From 15 to 20 per cent of fruit has been found to be necessary. However, the acidity of the finished product must be increased by adding either citric or tartaric acid. The acidity content should be 0.6 to 0.8 of 1 per cent.

Titration with 0.1N sodium hydroxide solution, with phenolphthalein as indicator, has been found to be a satisfactory commercial test for acidity in ices and sherbets. Since many ices are colored pink, it would seem that the end point could not be secured with phenolphthalein as the indicator. However, the solution becomes almost colorless before the end point is reached, so that the color change at the end point is easily observed.

A Study of Ice Creams High in Fat Content. (M. J. Mack). In New England during the past 5 years, many small ice cream concerns have organized for a specialized type of business. They sell only ice creams of high fat content and do only a retail business, usually through attractive road-side stores.

The majority of these dealers buy a prepared basic mix through one of a small number of concerns specializing in this type of product. Obviously, it would be more economical if the dealer were to prepare his own mix as well as freeze it. However, difficulties arise in the preparation of a basic mix of this composition. Therefore, this project has been started with the objective of securing information concerning ice creams of this composition. No published work on this subject is availiable.

From the data now available, it is apparent that ice creams of a higher fat content than 18 per cent should contain no more serum solids than are furnished by the milk and cream used in their manufacture. As the fat content increases, the homogenization pressure must be decreased. A pressure of 800 to 1000 pounds is sufficient for an ice cream containing 20 per cent fat. Sufficient stability is secured from the fat and gelatin. Aging for 24 hours seems more beneficial than with ice creams of lower fat content. A high drawing temperature of about 25.5° F. must be maintained if the freezing time and yield are to be satisfactory.

To date it has been very difficult to introduce frozen cream or butter as the source of fat, for an extremely viscous product results. As the study progresses it is hoped that this and other problems pertaining to the manufacture of high fat ice creams can be successfully met.

A Study of the Effect of Various Initial Aging Temperatures on the Behavior of Gelatin in Ice Cream. (W. S. Mueller). The continuation of this study during the past year has definitely shown that aging an ice cream mix containing gelatin for 4 hours at 68° F. results in an increased efficiency of the gelatin. Of the various initial aging temperatures tried, which ranged from

50° F. to 149° F., 68° F. gave the maximum increase in gelatin efficiency. The following results were obtained when mixes aged at 68° F. for 4 hours were compared with mixes aged at the customary temperature (40° F.).

1. Improvement in texture.
2. Firmer body.
3. Increased melting resistance.
4. Slight reduction in overrun.
5. Increase in basic viscosity and gel strength when followed by a low aging temperature period.

Increasing the gelatin concentration and also the strength of gelatin (Bloom test) increased the magnitude of the high aging temperature effects. As would be expected, the mixes with low total solids were found to be benefited more by the use of a high aging temperature than were the mixes with high total solids.

The use of a 68° F. initial aging period was found to be equivalent to approximately 0.1 per cent gelatin.

A check on the possibility of any increase in bacterial growth, titratable acidity, or pH when the mix is aged at 68° F. for 4 hours showed no increase which would be of any consequence in commercial ice cream manufacture.

In an effort to ascertain the reasons for this behavior of gelatin, a thorough study of the physical properties of gelatin is being made. A study of the optical rotation of gelatin is now well under way.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials Which Promise Value in Insect Control. (A. I. Bourne). A recent development in the field of oil sprays is the appearance on American markets of tar distillate oil emulsions which have been in general use in Europe for several years. In Europe, these oils are products of the distillation of coal, lignite and, to some extent, wood; in America, much of the material is obtained from coke ovens. Samples of both the English and the American oils were used in the tests. These oils did not prove to be as satisfactory indicators on trees in the orchard as are most of the common oil sprays; consequently a tendency to overspray the trees was unavoidable. In dormant application the English samples showed a slight tendency to retard the growth of leaf and blossom buds; the American samples did not. When applied at late dormant or delayed dormant stages of bud development, all of the oils caused severe burning and, in many cases, outright killing of the buds. In these tests the oils were not particularly effective in killing the overwintering eggs of the European red mite, being considerably inferior to most of the common oil sprays.

Tests with the typical American oil sprays included several new products which have recently appeared on Massachusetts markets. Of these, Free Mulsion (Sherwin-Williams Co.) and Oil-tone (Lucas Kil-Tone Co.) gave very satisfactory results, particularly when used at a dilution of 5 gallons to 100. Kleenup again gave a high degree of control. The red mite infestation was much heavier in the college orchards than in 1930. This emphasized the necessity for a high degree of control of the overwintering eggs, and strengthened the belief that in combating a heavy infestation the stronger dilutions of oil emulsions are advisable.

Of the miscible oils, Sunoco maintained its usual high degree of effectiveness. Scalecide was somewhat less effective than in earlier tests.

Weather conditions during early spring were very favorable. Most of the delayed dormant applications were made at temperatures of 55° to 65° F. No injury was noted following any of the oils tested. Tests of comparative coverage of two standard brands of miscible oil, an oil emulsion, and commercial lime-sulfur applied under similar weather conditions and to trees of uniform size and spread, again showed a marked advantage of the oils over lime-sulfur both in time necessary for application and in amount of material used, the oils requiring noticeably less material and approximately two-thirds of the time necessary for equivalent coverage by lime-sulfur. The tests failed to show any significant advantage of one type of oil over another, in these respects.

Further studies of various spray materials and combinations were made, in cooperation with the Department of Pomology. Especial attention was directed upon their compatibility, effectiveness as insecticides and fungicides, and relative toxicity to fruit and foliage as compared with the standard combination of lead arsenate and lime-sulfur. All the materials were applied in combination with lead arsenate, since up to the present this has proved superior to any other arsenical for general orchard use.

Combinations of lead arsenate with Sulfocide, with dry lime-sulfur, and with dry mix sulfur lime were compared with the usual combined spray of lead arsenate and liquid lime-sulfur with and without the addition of hydrated lime. These tests were made in a block containing five standard varieties of apples, namely, Baldwin, Northern Spy, R. I. Greening, McIntosh and King. The spray schedule consisted of a pre-pink, a pink and a calyx spray and two cover and two July sprays for apple maggot.

The addition of hydrated lime to the lead arsenate–lime-sulfur combination checked somewhat but did not entirely prevent spray injury to foliage. Considerable burn was noted on all varieties sprayed with the Sulfocide combination. Burn was particularly noticeable on Baldwin and King, and was accompanied by considerable yellowing of foliage and some premature drop of leaves. Dry lime-sulfur caused very little burn even on susceptible varieties. No burn was noted following the application of dry mix sulfur lime. Both Kolofog and flotation sulfur combined with lead arsenate and applied in a similar schedule to a block of McIntosh and Baldwin showed excellent persistence and gave very uniform coverage. No foliage injury was noted following the use of flotation sulfur, and but a very slight amount of burn on trees sprayed with Kolofog. The lead arsenate–lime-sulfur spray in this orchard caused extensive burn on Baldwin and considerable foliage injury on McIntosh.

The relative effectiveness of these materials is shown in the following record of McIntosh at harvest.

The addition of hydrated lime to the lead arsenate–lime-sulfur combination apparently did not impair the insecticidal value of the spray but did not give as successful control of scab as did the standard combination without lime. The Sulfocide combination failed to control scab satisfactorily and was not conspicuously successful as an insecticide. Dry lime-sulfur and lead arsenate gave good control against insects and held scab as successfully as did liquid lime-sulfur. The dry mix combination gave practically the same results as did dry lime-sulfur. Flotation sulfur and lead arsenate held scab very successfully and showed good control of insects. Kolofog did not control scab quite as well but did not impair the insecticidal action of lead arsenate.

McIntosh Apples, Block A

Treatment	Percentage of fruit showing: Insect Injury	Scab
Lime-sulfur, Lead arsenate	27	16
Lime-sulfur, Lead arsenate, Lime	16	24
Sulfocide, Lead arsenate, Lime	23	39
Dry lime-sulfur, Lead arsenate	9	17
Dry mix sulfur lime, Lead arsenate	9	16
*Check		

McIntosh Apples, Block E

Flotation sulfur, Lead arsenate	15	0.5
Kolofog, Lead arsenate	13	5.0
Lime-sulfur, Lead arsenate	18	0.5
**Check	110	35.0

*All fruit dropped; practically 100 per cent of it scabby.
**55 per cent had more than one blemish.

Similar results were secured on Baldwin. Scab was, however, less conspicuous on that variety and some differences in insect injury were noted, principally due to the longer growing season of Baldwin.

Control of Onion Thrips. (A. I. Bourne). The early season, marked by relatively high temperatures and abundant rainfall, was favorable for the growth of both seed and set onions, while the frequent and heavy rains offered less favorable conditions for the rapid development of thrips. The infestation throughout the Connecticut Valley was comparatively light and somewhat lower than in 1930. No fields were observed where thrips caused serious damage. In most of the fields of seed onions adjoining sets, the infestation was only moderately heavy, while those isolated from sets were comparatively free from thrips.

The seasonal development of thrips closely followed the normal except for a rather heavy migration of winged adults from sets late in June which took place during a period of unusually high temperature.

The great migration of thrips from sets occurred somewhat earlier than the date of the pulling of the set onions and coincided very closely with the date when those plants had matured and before they had broken over and fallen.

Studies of the effects of environment on thrips abundance in a field of seed onions exposed on the north to sets and on the south to grassland indicated the relative danger of early and heavy infestation from both sources, because of the opportunity for rapid increase offered by the sets and the excellent hibernation quarters furnished by grassland. Examination of this field, at the time when the

sets were maturing and shortly after the field to the south was mowed and hay removed, showed the following infestation.

Section of plot	Thrips per 100 plants
North side, adjoining sets	1900
South side, adjoining grassland	1760
Center	600

As the season advanced the gradual spread of the insects from each border had resulted in a heavy and more nearly uniform infestation throughout the entire field, as shown by the following.

Section of plot	Thrips per 100 plants
North side	4230
South side	3120
Center	2175

Applications of the nicotine-soap combination were sufficient to check thrips on seed onions exposed to infestation from sets. This was due in large part to the early maturity of the sets and the fact that the principal migration of thrips took place somewhat earlier than normal. Infestation was reduced from an average of 1200 thrips per 100 plants to 125 thrips per 100 plants in one field following an application of the above spray. A similar application in a second field reduced the numbers of thrips from an average of 3250 per 100 plants to 190 per 100 plants.

Predacious insects were present in such insignificant numbers that they played little or no part in checking thrips infestation.

The study of the effect of sprays and dusts on onion blast was continued in cooperation with the Department of Botany, and the work has been reported in Bulletin 279.

The Spray Residue Problem. (A. I. Bourne). Abundant rainfall throughout the summer and early fall for the most part automatically disposed of the problem of spray residue this past season. Most of the excess precipitation occurred in late August between the last applications of spray or dust and harvest. McIntosh and later varieties were practically free from residue, even in those orchards where late July sprays were applied for the control of apple maggot.

Further studies of the value of dusts for the control of late season pests such as apple maggot, late codling moth, etc., again emphasized the advantage of dusts over sprays for late summer use. Timeliness is a factor of major importance at that season. Dusts allowed a much more flexible schedule than did sprays. This advantage, coupled with the fact that dusts may be safely used during August within two to three weeks of harvest, rather more than offsets the undeniably superior persistence of sprays.

Systematic Study of Oil Sprays. (A. I. Bourne in cooperation with the Department of Chemistry). Nine samples of oil sprays prepared by the Chemistry Department were tested in the orchard to check their effectiveness against European red mite and toxicity to plant growth. The samples consisted of three different types of light lubricating oils, each combined with three different emulsifying agents. All of the samples went into solution readily, and once diluted formed a stable solution with no tendency for separation of oil, even upon

long standing. In application all the oils proved to be good indicators on the trees. There was no evidence of any retarding of development, tip burning or killing of fruit or leaf buds following any of the oils.

All the samples gave a very satisfactory kill of the overwintering eggs of the European red mite (97 per cent or better).

Apple Maggot Control. (A. I. Bourne). Control demonstrations were continued in the ten orchards in which the growers carried out the recommended program in 1930. Two additional orchards, in both of which apple maggot had been a serious pest the previous year, were included in the 1931 tests.

The same program was outlined for the growers as was followed in 1930. Particular stress was laid upon the value of close observation of the trees to detect the first appearance of the flies and their relative abundance throughout the season and thus allow better timing of the sprays or dusts. Examination of the McIntosh crop at harvest showed an average of 0.9 per cent maggot injury. In the ten orchards included in the demonstration for the second successive year, eight of the growers carried out the program in full. Maggot injury in these orchards averaged 0.5 per cent. Two of the growers carried out the program only in part. Samples checked in these orchards showed 3 to 4 per cent infestation. In the two new orchards included this season, maggot injury was held to a low figure. Their fruit showed infestation of 0.2 and of 2 per cent.

In no case was excessive spray residue found on the fruit. Growers who dusted for late applications secured fully as good results as did those who depended entirely on sprays.

A very encouraging feature of the season's results was that, without exception, growers in these tests secured better control of apple maggot than of any other major disease or insect pest.

Control of the Plum Curculio in Apples. (W. D. Whitcomb, Waltham). The activity of the plum curculio in 1931 was concentrated in the period of hot weather from May 27 to June 1, inclusive, when much damage was done to apples. However, the activity and development throughout the season appeared to be less than usual for only 1618 mature larvae emerged from a bushel of unsprayed dropped apples, compared to an average of 2854 for the three previous seasons.

In a study of hibernating environment, no beetles survived when buried in wire cages from 3 to 12 inches beneath the surface of the soil. A small number of beetles survived in cages having a protection of leaves and the survival was greater among beetles which were placed in hibernation October 1 than on September 5 or 15.

When confined in constant-temperature cabinets, eggs, larvae, and pupae died at 55° F., and development was greatly retarded at 65° F. The most favorable temperature appeared to be 75° F. where the development was slightly faster than at 85° F. The period of growth of larvae in the apples was not greatly changed at any of the effective temperatures.

The greatest number of feeding and egg punctures by adults occurred at 75° F.

Temperature °F.	AVERAGE NUMBER OF PUNCTURES PER BEETLE PER DAY		
	Egg Punctures	Feeding Punctures	Total
55	0.130	0.895	1.025
65	0.445	1.960	2.405
75	1.015	5.660	6.675
85	1.035	5.020	6.055

When the beetles were confined with poisoned fruit at the same constant temperatures, the number of days they lived decreased at each succeeding higher temperature, with the greatest decrease occurring between 55° and 65° F. With few exceptions, the average number of punctures per beetle increased at each successive higher temperature, but the rate of increase was small and somewhat inconsistent. At all temperatures the average length of life decreased with the increased concentration of lead arsenate until 6 pounds per 100 gallons of water was used when there was a slight increase in length of life, indicating a repellant action. These records indicate that 5 pounds of lead arsenate in 100 gallons of water was the most effective concentration to use, but the difference between that and 4 pounds per 100 gallons was slight. The addition of fish oil showed little effect in these experiments, but its use is advisable in field applications to increase adherence and spreading. A complete orchard formula containing lime-sulfur and hydrated lime was slightly less effective at the two lower temperatures but one of the best at the two higher temperatures.

The relative effectiveness of a dust and spray program for the control of the plum curculio where the fruit grower made the applications was studied under orchard conditions. The sprayed block contained Gravenstein and Astrachan, and the dusted block was made up of Gravenstein and Wealthy. Standard treatments were applied to all trees on the same day, as nearly as possible. Both blocks received liquid sprays through the calyx application. Including the "drops," 42,440 apples were examined with the following result:

Variety.	PERCENTAGE OF APPLES STUNG	
	Sprayed	Dusted
Gravenstein	8.54	9.43
Astrachan	4.28	.....
Wealthy		2.90
Total	5.74	6.12

Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb, Waltham). As in 1930, the carrot rust fly was not present in sufficient numbers in eastern Massachusetts to be considered an important pest, although reports from Maine and other northern localities indicated greater numbers there.

When confined at constant temperatures, 68 per cent of the flies emerged at both 55° and 65°F.; 42 per cent at 75°; and none at 85° F. In soil with a moisture content of 25, 50, 75 and 100 per cent of its capacity at saturation, the emergence decreased from 70 per cent at 25 per cent saturation to 2.5 per cent at 100 per cent saturation. The average date of emergence decreased consistently from May 19 with 25 per cent saturation to May 25 with 100 per cent saturation, with only one individual surviving in the extremely wet soil. The flies lived longest at 55° F. but laid the greatest number of eggs at 65° F., these lower temperatures being much more favorable than the higher (75° and 85° F.). Undoubtedly temperature and moisture during the oviposition period of the first generation determine the abundance of the insect in each season. The use of an

irrigation system to maintain plenty of moisture during oviposition resulted in only a 2 per cent greater injury to carrots by the first generation but caused 13 per cent greater injury by the second generation.

The field infestation at Waltham was again so light that date of planting and variety susceptibility records were of little value, although a 38 per cent infestation in White Belgian by the first generation indicated that this variety is susceptible.

Studies of control by insecticides were greatly handicapped by the light infestation. Under the existing conditions Scotch Soot and tobacco dust were the most satisfactory, both giving nearly perfect control with a slight stimulation to the plants. These materials were applied to the crown of the plant and adjacent soil by hand at the rate of about 5 pounds to 180 feet of row.

Napthalene and Similar Materials as Fumigants for the Control of Greenhouse Insect Pests. (W. D. Whitcomb, Waltham). Fumigation with vaporized naphthalene is an effective treatment for the control of most injurious insects and mites on greenhouse plants, and with a few exceptions can be used safely when the proper conditions are maintained. In a tight chamber, the fumes from 1½ ounces of melted naphthalene per 1000 cubic feet of air killed 93 per cent of the red spiders in one fumigation of 6 hours; but 2 or 3 ounces per 1000 cubic feet have been found necessary to counteract the leakage and adsorption in commercial greenhouses. An exposure of 4 hours is necessary to cause any appreciable kill of red spiders. Under ideal conditions, two or more fumigations using 3 ounces per 1000 cubic feet killed all red spider eggs; 12.5 per cent hatched after one fumigation, and 89 per cent of the unfumigated eggs hatched. Eggs which were 4 or 5 days old were killed more easily than newly laid eggs. The protonymphal stage of the red spider was most easily killed and the deutonymphs and adult males appeared the most resistant. Three or four fumigations are often necessary to obtain a satisfactory kill of red spider, and it was found that an interval of 1 day between treatments was more effective than an interval of 2 or 3 days, and that an interval of 3 days was 5 per cent more effective than an interval of 2 days.

Fumigation under controlled atmospheric conditions, ranging from 60 per cent to 90 per cent relative humidity and including 75° and 80° F., showed a slight but regular decline in effectiveness from the higher to the lower humidity, and a slightly increased kill at 80° F. over 75° F. However, there was a tendency toward plant injury at 90 per cent relative humidity, and the most favorable condition appeared to be a relative humidity of 80 per cent and a temperature of 80° F.

The addition of 15 per cent paradichlorobenzene to the naphthalene tended to increase the effectiveness of the fumigation with one treatment, but this formula and naphthalene alone were equally effective in two or three fumigations.

Thrips are more easily killed by this treatment than other insects although aphids and white flies are easily controlled by two or more good fumigations. Mealy bugs are very resistant, and the fumes will not penetrate the soil sufficiently to kill bulb mites. Exposed cyclamen mites are killed by 3 or more fumigations, and treatments at regular intervals keep this pest in check satisfactorily.

Carnation, begonia and cyclamen tolerate naphthalene at strong concentrations and can be fumigated safely in any greenhouse in which the necessary temperature can be maintained. Freesia, oxalis, violet and fuchsia are very susceptible to injury and should not be fumigated unless the temperature, humidity and concentration can be controlled absolutely. Chrysanthemums appear to

have a varietal tolerance which has not yet been determined. The majority of other common greenhouse flowering plants have been fumigated safely but have a small margin of safety. Tomato and cucumber plants tolerate naphthalene but the fruits absorb the odor and taste of the fumes, making the treatment undesirable.

DEPARTMENT OF FARM MANAGEMENT

J. A. Foord in Charge

Enterprise Relationships and Farm Organization on Selected Dairy Farms in Western Massachusetts. (R. L. Mighell). Bulletin 275, published during the year, explains the re-planning of three dairy-fruit farms, and the probable results. Some further work has been accomplished on time studies of farm operations, especially of chores on dairy farms.

Types of Farming in Vegetable Garden Areas. (F. H. Branch, R. L. Mighell, J. E. Thigpen). This is a cooperative project with the Extension Service, as previously noted. From the records obtained in 1930 the amount and distribution of labor expended on the different operations incident to the production of the important vegetable crops in eastern Massachusetts was determined and mimeographed for use in Extension work and at Farm and Home week. This caused a demand for the material in the Agricultural Schools and High School Departments of Agriculture, and several hundred copies were prepared for this use. Other studies are in progress.

A Study of Labor Saving Methods and Technique on Vegetable Farms. (R. L. Mighell, R. H. Barrett, J. E. Thigpen). This is a new project, intended first to develop principles and procedure for the study, and then to determine actual labor saving methods and technique. A good many studies have been made of different operations on vegetable farms, aided by the stop-watch, and both the moving picture and still camera. The crops so far considered are asparagus, carrots, beets, celery and tomatoes. A demonstration was given on the Field Day at the Waltham Field Station and some moving picture films have been prepared for use at growers' meetings.

Live Stock Management, Methods and Costs. (J. A. Foord). Those animals in the college herd showing a positive reaction to the blood test for Bangs disease have been segregated for two years ending November 1, and the labor and material costs are being assembled for use and possible publication.

The Cost of Silage Production in Massachusetts with Special Reference to the Use of Machinery. (C. I. Gunness, J. A. Foord, J. E. Thigpen). This is a cooperative project between the Bureau of Agricultural Engineering, U. S. D. A., and the Departments of Agricultural Engineering and Farm Management of the Experiment Station. Enterprise records have been obtained from more than sixty farmers in the four western counties, and for areas of from seven acres to sixty acres on individual farms. The material will be tabulated and prepared for publication during the winter.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, G. J. Larsinos, F. A. McLaughlin, J. T. Howard). During the fiscal year, 1,591 samples of feeding stuffs were officially collected and examined in the control laboratories. The results show that at least 96 per cent of the samples collected varied less than one per cent from stated guarantees in protein, fat and fiber content. The gross receipts from the registration of feeding stuffs in 1931 (calendar year) were $21,320, derived from 1,066 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, Margaret E. Nagle). From October 1, 1930, to October 1, 1931, the seed laboratory analyzed 1,135 samples of seed, of which 469 were collected by the State Commissioner of Agriculture, 216 sent in by dealers and farmers, 212 received from the Rhode Island Commission of Agriculture, and 238 purchased from wholesalers for special tests. Classification of these analyses is shown by the following summary.

Summary of Samples Analyzed

	Massachusetts Official	Massachusetts Non-Official	Rhode Island	Totals
Purity analysis only	34	23	25	82
Blotter germination tests	306	368	2	676
Soil germination tests*		125		
Field germination tests*		238		
Purity and germination	129	63	185	377
				1,135
Field crops	21	79	29	129
Forage crops	142	102	181	425
Vegetable seeds	306	266	2	574
Tree seeds		7		7
				1,135

* Samples germinated in soil and field are duplications of 238 samples of vegetable seeds germinated in blotters.

Field tests to determine trueness to type were again conducted in cooperation with the Department of Agronomy which tested 9 samples of alfalfa, 12 samples of red clover, and 2 samples of sweet clover, and the Department of Vegetable Gardening which tested 125 varieties and strains of varieties of onions, and 113 samples of peas.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen). During the year ending December 1, 1931, 7798 pieces of Babcock glassware were tested. Condemned glassware consisted of one cream test bottle. Eighty-one certificates of proficiency were awarded.

One hundred and sixty-six creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, two machines were condemned outright, major repairs were ordered on six, and minor repairs on twenty. Where it is thought necessary, re-inspections will be made. Special investigations were made at ten plants.

Advanced Registry Testing. (P. H. Smith). Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 528 cows located on 67 different farms. This does not include the herd tests where all animals in each herd are placed on test. Of these there are fourteen, two of which are supervised by men sent out from this office and twelve by cow test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, G. J. Larsinos). Numerous analyses have been made for residents of the State and other departments of the College. Especial attention is called to the increasing number of dry matter determinations in connection with forage crop experiments. This work has become a real burden upon other work of the department and should it increase materially, the employment of an additional assistant during the summer months will be necessary.

Summary of Miscellaneous Work, 1931

Materials sent in:	
Milk and cream, butterfat only	461
Milk, solids and fat	4
Feeds	104
For other departments of Experiment Station and College:	
Milk, for butterfat	138
Milk, for solids	10
Dry matter, forage crops	2,255
Complete fodder analyses	167
Dry matter and nitrogen	49

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, A. F. Spelman, G. J. Larsinos, and J. B. Zielinski, Jr.). During the season, 125 firms or individuals have registered for sale in Massachusetts 589 brands of mixed fertilizers and fertilizing materials and 26 brands of agricultural lime and gypsum. Statistics with reference to the inspection of these products are given in the following summary.

The four agents who secured samples of fertilizer and lime for the year's inspection sampled 24,925 sacks or containers, representing 10,753 tons of material; 873 agents were visited.

Products	Brands Registered	Brands Collected	Samples Collected	Number of Analyses	Number of Determinations
Mixed fertilizers	357	344	1207	467	6071*
Ground bone, tankage and fish	56	50	165	65	301
Nitrogen products, organic and mineral	71	64	270	177	531
Phosphoric acid products	31	27	117	32	128
Potash products	21	21	72	32	116
Cotton hull ashes and wood ashes	9	8	12	11	46
Ammoniated superphosphates	4	4	5	4	40
Nitrate of potash	7	6	12	9	36
Dried, pulverized natural manures	23	23	94	22	110
Peat products	7	7	10	6	30
Miscellaneous	3	3	9	4	23
Lime products	26	26	68	27	190
Totals	615	583	2041	856	7622

* Not counting check tests or repeats, which would amount to at least one-third more in number.

From July 1, 1930, to July 1, 1931, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons)		
		Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	43,463	1,916	3,473	2,827
Unmixed fertilizer chemicals and materials	19,174	1,084	1,630	561
Pulverized natural manures	2,426	42	30	87
Totals	65,063	3,042	5,133	3,475

Full details of the fertilizer and lime inspection will be found in Bulletins 60 and 61, Control Series.

Miscellaneous Analytical Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, and G. J. Larsinos). The cooperative chemical work which was carried on with other departments of the Experiment Station covered the usual range of projects and comprised the following analyses:

Cured hay, partial ash analysis	53
Pasture grass, partial ash analysis	22
Peat, fertilizer analysis	2
Farm manures	4
Complete fertilizers	6
Unmixed fertilizer materials	23
Ashes of peat	1
Charcoal	2
Iron sulfate	2
Soils, special study tobacco root-rot	12
Soils, mechanical analysis	12
Soils, partial analysis	4

Requests for analyses from farmers and farm organizations have received the usual attention. A nominal charge has been made for such work when of interest only to the individual. Results of analysis are always interpreted and suggestions are made as to the practical application of the work. The following materials have been examined under this heading:

Unmixed fertilizer materials	10
Complete fertilizers	3
Lime products	3
Manufacturing by-products	6
Farm manures	2
Peat products	12
Miscellaneous	7
Soils, partial analysis	28

The usual interest has been taken during the year in the work of the Association of Official Agricultural Chemists, Mr. Haskins having served as President of the Association and as Chairman of the Committee on Definition of Terms and Interpretation of Results on Fertilizers and Lime Products.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Study of the Effect of Plant Nutrients on Carnations and Roses Under Glass. (H. E. White, Waltham). Experimental work has been carried on with different fertilizer materials to determine what effect the sources of nitrogen and phosphorus may have upon the growth of carnations and roses.

There have not been any outstanding differences in the number or quality of carnation flowers produced by the plants in the different fertilizer plots. Applications of nitrogen in the short, dark days of December did not noticeably increase splitting of calyces. Plants receiving calurea, urea, and blood produced a few more split calyces than plants in some of the other treatments, with the exception of the manure plots. Splitting of calyces appears to be a genetical tendency or varietal peculiarity. Spectrum has a greater tendency to split than either Ivory or Woburn. Nitrogen starvation symptoms appeared by midwinter on the manure and peat plots; light applications of sodium nitrate restored the plants to their normal condition.

A peculiar physiological disturbance was observed in the sodium nitrate plots. The petals of the affected flowers grew out beyond the calyces but they appeared to be glued together. When such flowers were soaked in alcohol, the bases of the petals were found to have adhered. However, the upper portions were easily freed from one another by the alcohol. This condition has been encountered in local greenhouses but so far the causes have not been satisfactorily explained. The manure plots which showed nitrogen deficiency and received sodium nitrate produced flowers showing this adhesion. Further investigational work is being carried on to determine the cause of this trouble.

There were no outstanding differences in the fertilizer trials with roses. The plots are being carried on for another season since the present plants have been in the plots for one year only. If the results warrant it, the work will be continued.

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (H. E. White, Waltham). In the summer of 1930 rust resistant plants of the Mains' strains from Purdue were selected in the field and planted in the greenhouse for breeding. Some 50 different crosses were made between these strains and greenhouse varieties. The progeny of these crosses, consisting

of approximately 8000 plants, were planted in the field and inoculated with rust during the summer of 1931. The different crosses showed varying degrees of susceptibility to rust. A number of very resistant white and yellow flowered individuals were selected from the F_1 generation for further breeding work. Further selections and breeding are being carried on to obtain resistance combined with qualities desired in commercial varieties.

DEPARTMENT OF HOME ECONOMICS

Bernice Wait in Charge

The Comparative Value of Milk and Tomato for Supplementary Feeding in Elementary Schools. (E. Davies, B. Wait, and M. V. E. Voorneveld). This study of experimental supplementary feeding of children in a small consolidated rural school is being continued for a third year. Observation of the children indicates that there was some improvement in their general well-being as a result of the feeding either of milk or of tomatoes. Whether the data obtained will confirm this observation, or whether the improvement in the condition of the children was sufficient to be measured by the tests applied, cannot be ascertained until the tabulation of the data has been completed.

The Value of Evaporated Milk for School Food Service. (E. Davies, B. Wait, and O. A. Merriam). In this project, which is similar in method and purpose to the above, evaporated milk is being given to the children of the first four grades in the schools of a small mill village. The children of the same grades in the schools of a neighboring village are being used as a control group. While the tabulation of the data obtained from the first year of the study has not progressed to the point where definite conclusions are warranted, general observation of these children, as of those receiving fresh milk and tomatoes, suggests that there is an improvement in the general well-being of the children as a result of the school feeding.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Fruit Juices and Jelly Making. (C. R. Fellers). Three summers' work on methods of extracting juices from small fruits for jelly manufacture has now been completed and the results tabulated.

The examination of sodium benzoate samples for suitability as cider preservatives has been continued. Marked differences exist among these preparations as to ability to impart flavor. Several new German preservatives, derivatives of benzoic acid, show very promising results in cider preservation.

A new type of jelly tester was designed with J. A. Clague and thoroughly tested with the cooperation of Chatillion Bros., instrument makers, of New York. A description of the instrument appears in *Industrial and Engineering Chemistry, Analytical Edition*, 4:106-7, 1932. This new instrument combines low cost, adaptability, ease and speed of operation, mobility, and simplicity. Its use will enable manufacturers of fruit or pectin jellies to control consistency in their product. The tester works equally well with canned cranberry sauce.

Work was completed and a paper presented before the American Chemical

Society in September, 1931, on "A rapid centrifugal method for pectic acid determination." This paper has been accepted for publication by *Industrial and Engineering Chemistry*. The method greatly shortens the usual analytical procedure for pectin determinations in fruit products.

Effect of Microorganisms on the Jellying Power of Fruit Juices. (C. R. Fellers, J. A. Clague, and R. L. France). Data obtained in this cooperative project with the Bacteriology Department show that yeasts do not affect the jellying power of pectinous solutions. Several molds, however, are very active in the decomposition of pectin and render fruit juices containing them incapable of being used for jelly. Bacteria will be next studied in this connection.

Preservation and Nutrition Studies with Cranberry Products. (C. R. Fellers and J. A. Clague). Further laboratory and commercial experience has proved that canned cranberry sauce should have a soluble solids content of approximately 42–43 per cent. At our suggestion commercial canners are now using Abbe refractometers to control the finishing point on canned cranberry sauce. By this means uniform consistency and maximum yields are obtained.

Dr. H. J. Franklin of the Cranberry Station furnished us with 39 varieties of Massachusetts-grown cranberries last year and 25 varieties of New Jersey and Wisconsin cranberries this year. These varieties are being tested for suitability for manufacture of strained and whole-fruit cranberry sauce. Results to date indicate that only a few varieties are suitable for sauce; the only way some of the poorer varieties can be used at all is by blending. Each variety is also tested for pectin and benzoic acid. Preliminary analyses indicate a great variation among varieties in benzoic acid content; for example, the Early Black has 0.04-0.05 per cent as against 0.09-0.10 per cent in Howes variety. We plan to see if there is any relation between keeping qualities of varieties and benzoic acid content.

Vitamin studies (C. R. Fellers and P. D. Isham) on cranberries and cranberry products have been continued with the aid of funds made available by the American Cranberry Exchange. Cranberries and wild blueberries are moderately rich sources of vitamin C, from 3 to 4 grams daily sufficing to protect 300-gram guinea pigs. Unstrained cranberry sauce retained about 80 per cent of the vitamin C; but the strained sauce, pasteurized juice, and dried cranberries contained scarcely any of this vitamin. Studies are now under way to determine the vitamin A, B, and D potencies of cranberries. The work on blueberries will also be continued.

Physiological studies on human subjects showed that large doses of cranberries (100 grams or more) greatly increased urinary acidity and markedly lowered the blood alkali reserve. Small daily feedings of 22 grams produced no acidosis but did increase the acidity of the urine. Indirect calculations from the hippuric acid content of the urine following cranberry ingestion lead to the conclusion that from 0.6-0.85 per cent of quinic acid or a related substance is present in cranberries. This substance acts similarly to benzoic acid in the body and like the latter is eliminated as hippuric acid.

Methods of extraction of cranberry juice are being studied with the cooperation of C. C. Rice. Cranberry juice makes a popular beverage and is especially suitable for blending purposes because of its high flavor, acidity, and color.

Utilization of Onions by Canning and Drying. (C. R. Fellers). The continued examination of experimental packs of canned onions has further

proved that, with careful attention to details, onions may be successfully canned. Cooperative work on discoloration in canned onions has been conducted with C. P. Jones of the Department of Plant and Animal Chemistry.

Cull onions were again dehydrated and manufactured into onion powder. This powder retains all the natural flavoring principles of the onion, even after two years' storage in sealed containers. Samples have been distributed to various persons and agencies with a view to popularizing this new product.

Utilization of New England Fruits in Ice Cream. (C. R. Fellers and M. J. Mack). This cooperative project with the Department of Dairy Industry is now in its third year. The data are being assembled for a bulletin.

Effect of Freezing and Thawing on Microorganisms in Foods. (C. R. Fellers). The bacterial content of vegetables, fruits, meats, and fish which had been frozen for a year was determined. A similar determination was made after the frozen products had been defrosted for 24 hours. In general, the solidly frozen foods contained few bacteria (0-270,000); while, after defrosting at room temperature for 24 hours, the numbers were excessive in the case of vegetables, eggs, and oysters, and actual decomposition was evident. Manifestly, frozen vegetables and marine products should be promptly consumed after defrosting. Frozen fruits were still relatively free from spoilage and edible 48 hours after defrosting. A paper on "Public health aspects of frozen foods" was read before the American Public Health Association in September, 1931, and has been accepted for publication in the journal of the association.

Research on Dates. (C. R. Fellers and M. M. Cleveland). This investigation is financed by The Hills Brothers Company of New York. The study of the mineral composition of dates over a three-year period has been completed. The ash of dates is high and contains over 40 per cent K_2O, thus making the date an excellent acidity corrective.

A new product, known as date butter, was developed. This product will help utilize that part of the date crop which, though perfectly edible, cannot be sold as whole dates.

Dried date pulp is being tested for suitability for poultry food, in cooperation with the Poultry Department.

Vitamin Content of Baldwin Apples and Other Fruits. (C. R. Fellers and M. M. Cleveland). The native Baldwin apple has a relatively high vitamin C content. Feeding tests with guinea pigs showed no differences in the vitamin C content of sprayed and unsprayed Baldwins. Samples of fresh cider, pasteurized cider, lumpy (unstrained) apple sauce, and smooth, screened apple sauce made from Baldwin apples of known vitamin C content, are being tested for vitamin C.

Canned citrus fruits, oranges and grapefruit, contained fully as much vitamin C as the fresh fruits purchased in Amherst during July and August.

Canned Rat Baits. (C. R. Fellers in cooperation with E. M. Mills, Bureau of Biological Survey, U. S. D. A.). The canning of cereals, fish, and meat mixed with red squill has been perfected. In this way the baits will keep indefinitely, are convenient to use, and can be packed at a central factory and shipped to demonstration centers as desired.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY

J. B. Lindsey in Charge

The Effect of Fertilizer and Cultural Treatment on the Nitrogenous Compounds of Havana Seed Tobacco. (E. B. Holland and E. Bennett). The analytical work on tobacco has been continued along similar lines as in previous years with the exception that many duplicate samples have been sweat to determine the effect of the additional treatment on the nitrogenous compounds of the leaf. In view of the fact that recent investigators have stressed the carbohydrates as a criterion of quality, it would seem advisable to broaden the inquiry and attempt to correlate the carbohydrates and nitrogenous compounds with burn and character of ash. Substantially all the chemical work planned for the season has been completed and the results await examination.

Tobacco Field Experiments. (Compiled by E. B. Holland and E. Bennett). Experiments in raising Havana Seed tobacco have been conducted on the station plots since 1924 to determine the effect of various cultural and fertilizer treatments on the total yield, grades, and market value of the crop. The data for the 1924-1930 crops inclusive have been recalculated and compiled for publication and present many interesting facts concerning the size and weight of leaf of the several grades under the various treatments.

Oil Sprays. (E. B. Holland). Work has been continued with a light paraffin base oil, a medium paraffin oil, and a naphthene base oil. Miscibles were prepared from all three lubricating oils by three methods and applied in field tests under the supervision of the Entomology Department, with satisfactory results.

Spontaneous methods of preparation again proved preferable to the old process requiring heat, and an organic base more efficient than alkali. The oils themselves have been submitted to various physical tests to determine their position in the field of lubricants.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-Legumes under Certain Defined Agronomic Conditions. (F. W. Morse). This year (1931) oats were grown on the non-legume areas and field peas together with oats on the legume areas. Nitrogen was omitted from all plots this year as has been the procedure in alternate years. Eight annual crops have been removed from the plots since the beginning of the experiment, and a summary of the results is given in addition to those of the current year.

Results from Plots 7 and 9 which have not received any nitrogen in fertilizers since 1882 are compared with those from Plots 8 and 10 which have received nitrogen regularly, the former in sulfate of ammonia and the latter in organic animal matter. The comparison for this year, however, is between no nitrogen and residual nitrogen from previous applications. The figures are averaged from each pair of plots.

The crops this year (1931) were harvested for fodder just as the seed began to fill out. It made little difference in the yields whether nitrogen had been omitted for fifty years or only one year. Combining peas with the oats increased the dry matter about 25 per cent and the nitrogen over 70 per cent.

Crops on the non-legume areas during the eight years were hay, corn fodder, Japanese millet, corn fodder, hay, hay, Japanese millet, oat hay. On the legume

Dry Matter and Nitrogen Removed from Non-Legume and Legume Areas in 1931 and in 8 years
(Pounds per Acre)

	WITHOUT NITROGEN		WITH NITROGEN	
	Dry Matter	Nitrogen	Dry Matter	Nitrogen
Non-Legume, 1931	2,105	26.9	2,194	28.0
Legume, 1931	2,600	45.8	2,659	49.5
Non-Legume, 8 years	23,886	254.9	33,395	354.5
Legume, 8 years	28,058	534.4	29,867	563.3

areas they were clover hay, corn fodder, soy bean fodder, corn fodder, clover hay, clover hay, Japanese millet, pea and oat hay. On the non-legume areas the plots which had received 180 pounds nitrogen in 8 years produced 9500 pounds more dry matter per acre which contained 100 pounds more nitrogen than was obtained from the plots that had been without nitrogenous fertilizer for 50 years. The use of leguminous crops made the nitrogenous fertilizers comparatively ineffective. The gain of 1800 pounds of dry matter and 29 pounds of nitrogen was due mainly to the non-leguminous crops used in the rotation.

The soil from each individual section of the plots was sampled and analyzed in 1924, 1927, and 1931. To check results, a few samples of 1924 and 1927 were again analyzed simultaneously with the samples of 1931. The repetitions varied only a trifle from the originals, proving that reagents had been carefully prepared in each season. The individual analyses are averaged and summarized in the table.

Percentages of Nitrogen in Surface Soil
(Depth 8 inches)

Year	WITHOUT NITROGEN		WITH NITROGEN	
	Non-Legume	Legume	Non-Legume	Legume
1924	.130	.135	.158	.133
1927	.190	.160	.195	.180
1931	.165	.170	.170	.168

The figures clearly show no deterioration in soil nitrogen in the absence of nitrogenous fertilizers, and no accumulation of nitrogen in the soil where they were used. Since 254 pounds of nitrogen were removed from the soil where no legumes had been grown for 8 years, it appears that this nitrogen was supplied by soil organisms which took it from the air. Growing leguminous crops in rotation doubled the amount of air nitrogen thus secured.

Chemical Study of Cranberries. (F. W. Morse). At the request of Dr. H. J. Franklin of the Cranberry Station, analyses were made of Early Black and Howes cranberries which had been produced in a comparison of dry bogs versus watered bogs during the season of 1930. Dry matter, total acids calculated as citric acid, and total sugar were determined, with the results shown in the following table.

Composition of Cranberries from Dry and Watered Bogs

	EARLY BLACK		HOWES	
	Dry Bog	Watered Bog	Dry Bog	Watered Bog
Dry matter, per cent	12.43	11.77	14.21	13.48
Total acid, per cent	2.29	2.28	2.06	2.08
Total sugar, per cent	3.60	3.31	4.34	3.81

Cranberries from the dry bog contained more dry matter and sugar. Acid was unaffected. The berries from the dry bog appeared slightly wilted in comparison with those from the watered bog and averaged smaller in size. Several varieties of cranberries were analyzed and were all within the range of composition reported in Bulletin 265.

Astringent matter, wax, and quinic acid have been determined in some of the most common varieties of cranberries.

Determinations of wax were made by extracting the dried and pulverized cranberries with carbon tetrachloride. This solvent was used instead of ether because ether will dissolve malic acid which occurs in cranberries. Besides the wax which exists in the skin, the extract includes oil from the seeds; but seeds form only a small part of the fruit. The percentages of wax extract in 14 varieties ranged from 0.34 to 0.63. The wax was subsequently separated into two substances, one soluble and the other insoluble in petrolic ether. The insoluble material is a dry, resinous substance, while the soluble is soft and greasy in appearance. The wax is similar to the wax in apple skins and further study of it is intended.

Astringent matter was determined by the usual method of titration with potassium permanganate, and fresh fruit was used. The range of percentages in 12 varieties was from 0.25 to 0.46. Variations between varieties were too narrow to explain differences in quality.

The presence of quinic acid in cranberries was first announced this year by Kohman and Sanborn (E. H. Kohman and N. H. Sanborn, Indus. and Engin. Chem. 23:126, 1931). It does not lend itself to a sharp quantitative separation from the citric and malic acids which occur with it in the fruit. A tentative method was devised based on the different solubilities of lead and calcium salts of citric, malic, and quinic acids. The range of approximate percentages in numerous determinations in 12 varieties was from 0.45 to 1.1 per cent.

Milk Substitutes in the Growing of Young Calves. (J. B. Lindsey and J. G. Archibald). The problem is worthy of continued study because of the demand for fluid milk and the lack of skim milk for feeding. During 1930 studies were made of the so-called dry feeding method which consisted of feeding milk for the first four weeks of the calf's life and then substituting a dry grain mixture and alfalfa or rowen. While it is possible to grow Holstein or other rugged calves by this method, they appeared thin and not in as satisfactory condition as those receiving skim milk or diluted skim milk powder for a longer period of time. Therefore we do not feel like commending it.

At present the following method is being used with a group of calves: Whole milk is fed for one week, skim milk powder in the proportion of 3½ ounces to each quart of warm water gradually substituted and fed until the calves are six to eight weeks old, then replaced by a dry ration using an animal meal instead of the more expensive skim milk powder. It is hoped that for conditions prevailing in Massachusetts some such method will prove satisfactory and economical. Thus fed, an average rugged calf would receive, up to four months of age, about 50 quarts of whole milk and 60 pounds of skim milk powder in addition to rowen or alfalfa and a grain mixture.

Two Systems of Dairy Cattle Feeding—High Roughage and Low Grain versus Low Roughage and High Grain. (J. B. Lindsey and J. G. Archibald). This project was organized and started in the autumn of 1928 and was intended to continue for several years. The object has been to determine the effect of

maximum roughage and low grain (1 pound of grain to 4½ pounds milk) fed to one group of cows, and minimum roughage and high grain (1 pound of grain to 2½ pounds milk) fed to another group, upon the economy of milk production and the condition of the cows as regards appearance, live weight, and breeding. The roughage has consisted of first-cut hay, rowen, silage and green forage fed in different amounts; and the grain, of a mixture of wheat bran, ground oats, corn meal, gluten feed, and cottonseed meal, mixed in different proportions for the two groups. A statement of the results from October, 1928, through February 1, 1931, follows:

	High Roughage	Low Roughage
Proportion grain to total feed, dry matter (per cent):		
October, 1928 to October, 1929	21.5	36.5
October, 1929 to February, 1931	19.1	35.3
Dry matter required to produce 100 pounds milk (pounds):		
October, 1928 to October, 1929	107	97
October, 1929 to February, 1931	118	107
Net energy required to produce 100 pounds milk (therms):		
October, 1928 to October, 1929	610	600
October, 1929 to February, 1931	639	636
Feed cost of 100 pounds milk:		
October, 1928 to October, 1929	$1.74	$1.75
October, 1929 to February, 1931	1.70	1.67

It is clear that the high-roughage cows required more dry matter to produce a definite amount of milk than the low-roughage cows. The calculated therms of net energy, however, did not vary much for either group. When it came to a matter of feed cost, the results were about the same in each case on the basis of market price for all feeds. While for a definite amount of feed the low-roughage ration produced more milk than the high-roughage ration, the feed cost per unit of milk was about the same.

It might be added that the cows in both herds kept in good condition and did not show breeding troubles, although it must be admitted that the low-roughage cows presented the better appearance.

Mineral Requirements for the Growth of Dairy Heifers. (J. B. Lindsey and J. G. Archibald). Results of one phase of this project have been published in the *Journal of Agricultural Research* 42:883-896, June 15, 1931, in an article entitled, "The calcium requirements of dairy heifers."

Work on the phosphorus requirements is being actively pursued, although it has been seriously interfered with by the loss of two heifers which reacted to the tuberculin test in February. Forty metabolism balance trials with eight heifers have been completed. Four of these heifers have received a basal ration low in phosphorus, while for the other four the basal ration has been supplemented with sufficient organic phosphorus to double the amount of that element fed. The work has not reached a stage which warrants reporting any results. During the year the capacity of the equipment for conducting balance experiments has been doubled by the addition of two more metabolism stalls.

Studies in the Chemistry of Pasture Grasses. (J. G. Archibald and E. Bennett). A final report summarizing three years' work on the original project reported on in 1929 and 1930 (of which the present project is an outgrowth) has recently been prepared for publication.

Other phases of the more comprehensive project have progressed to the following extent:

1. In a study on nitrogen partition to determine what portion of the nitrogen in grasses is combined in true protein and what portion may be combined in the amino form or in the even simpler forms of ammonia and nitrates, 26 samples of grass have been analyzed. Half of these came from quite heavily fertilized pastures and the other half from unfertilized pastures. Some of them were from the college and experiment station farms, others came from Middlesex and Worcester Counties. Two samples of a pure stand of white clover, one fertilized and the other unfertilized, were also included in the study. The analyses showed:

In fertilized grass, the amino nitrogen constituted approximately 11.3 per cent of the total nitrogen; in unfertilized grass, it amounted to about 8.5 per cent of the total nitrogen.

In fertilized white clover, the amino nitrogen was slightly over 23 per cent of the total nitrogen; while in the unfertilized white clover, it was slightly under 21 per cent.

Ammoniacal nitrogen averaged about 1.8 per cent of the total nitrogen where fertilizer had been used and about 1.0 per cent where it had not been used.

There were only slight traces of nitrate nitrogen in any of the samples.

2. The survey of natural pastures throughout the State had to be temporarily suspended this year because the soil maps of the important pasture areas still unsurveyed were not available, being still in process of publication. It is hoped to continue and complete this phase of the work next season. Analyses have been completed of forty samples taken in Worcester and Berkshire Counties in 1930, and the following conclusions are offered:

Results indicate a natural pasturage on the predominant soil types of Berkshire County superior in both quantity and quality to that on the predominant type in Worcester County. This is attributed to heavier soils with greater moisture-holding capacity.

Judged by the standard of a recognized authority, these pastures measure up quite well. In general the only deficiency suggested is in the element phosphorus.

The ratio of calcium to phosphorus is probably too high, due partly to the low phosphorus content and (in the case of at least one soil type) partly to a rather high calcium content.

3. The study of the chemical composition of different species of grass involved the collection in 1930 of 50 samples of grass from plots growing pure stands of timothy, redtop, blue grass and white clover; and the collection in 1931 of 60 samples from plots of orchard grass, sheep fescue, Rhode Island bent, and Canada blue grass, in addition to the above-mentioned species. Analysis of the 1930 samples has been completed and studied in detail. Analysis of the 1931 samples is now in progress. Conclusions on this phase of the work are withheld until more data have been accumulated.

Utilization of Onions by Canning. (C. P. Jones). This is a continuation of the study reported in the annual report for 1929 (Bulletin 260). Work during the past year has been confined largely to a study of the Yellow Globe onion and its behavior during and subsequent to canning.

Onions put up by the Department of Horticultural Manufactures and held in tin containers for two years, adsorbed more of the corrosion products of the can than was found in the liquor. Amounts determined were influenced some-

what by differences due to individual cans, type of can, and weight of onions packed.

A commercial brand of onions packed in enameled cans was examined five to six months after canning. Only a light brown discoloration of the onions developed upon long exposure to the air. Very little, if any, corrosion of the can was noted. Onions packed in similar cans and kept in storage for a little over two years, discolored considerably upon long exposure, the discoloration developed more slowly, and the ultimate color was more of a dark brown than dark olive green. Unfolding the cans revealed no evidence of corrosion at the junction of ends and sides or along the side seam. Discoloration of bulbs in this instance could not be associated with the metal of the can, and the cause must be looked for elsewhere.

The 1931 crop of commercially canned onions, processed in plain tin containers, was examined two to three months after canning and showed only a slight discoloration of the tinned surfaces of the can. Long exposure of the onions to the air failed to produce any appreciable discoloration. Treatment of the bulbs with dilute ferric chloride solution resulted in no discoloration. Improved methods of canning are probably responsible for this better condition. The onions were whiter and smaller in size than the Yellow Globe Danvers variety.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The crop of peaches in the Station orchards was about as large as that of 1930, but the apple crop was about one-half that of last year. This is probably due largely to the heavy crop of 1930. Studies of the air temperatures during and immediately following bloom showed that during this period in 1930, high temperatures prevailed to an exceptional degree. This may be the chief reason for the heavy crop. Fluctuations in crops during the past ten years did not follow the lesser differences in temperature very definitely.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw and J. S. Bailey). Alternate trees in the main orchard in this project were removed during the past winter. This project may be considered as finished though further observations on the remaining trees may be made. Eight rows of "permanent" trees were top grafted to new varieties in the spring of 1931.

This orchard has suffered in some years from a peculiar "tip burn" of the leaves. A trouble similar in appearance has been attributed to potash deficiency. In this orchard it is evidently correlated with water supply of the trees The orchard has never received any potash fertilizer so it was felt that a potash deficiency might be a factor. A strip involving two rows of trees was plowed in the spring and a liberal application of muriate of potash given to one of these rows. The tip burn was not prevalent in the orchard the past summer. There was no evidence that potash had any influence in the limited amount that appeared.

Efforts to propagate Malling Stocks by mound layering were continued. These are expected to yield a considerable number of rooted stocks when dug next spring. These will be used to establish a new and larger stock bed.

The orchard of McIntosh and Wealthy on Malling Stocks made a satisfactory growth during the season and showed considerable bloom and some fruit.

The average growth of the trees during the four years they have been in the orchard is as follows:

Increase in Trunk Diameter in Four Years
(Own-rooted trees=100)

Stock	McIntosh	Wealthy	Stock	McIntosh	Wealthy
1	99.7	50.2	10	89.4	93.6
2	13.1	41.2	12	98.4	126.6
3	7.7	20.6	13	77.3	98.9
4	114.7	104.9	15	79.6	99.3
5	80.9	94.0	16	106.4	134.8
6	77.3	76.8	Own-rooted	100.0	100.0
8	23.2	44.9	Seedling roots	93.8	109.0
9	27.1	33.8			

Stocks 4, 12, and 16 seem to be standard stocks, while the others dwarf these two varieties in varying degrees. The difference between the two varieties when worked on Stock 1 is exceptional. Stocks 2 to 9, inclusive, are represented in small numbers, which may well explain the differences which appear.

Tree Character of Fruit Varieties. (J. K. Shaw and A. P. French). Further studies of nursery trees of different varieties of tree fruits have been made in connection with the certification work of the Massachusetts Fruit Growers' Association and with inspection work in other nurseries. Photographs showing the varietal characters of one and two year trees as grown in the station nursery have been made. This work will be continued next year and should furnish material for a publication setting forth variety characters better than can be done in any other way. A revision of Bulletin No. 208 was published during the year as Bulletin No. 274, "The Identification of Apple Varieties from Non-Bearing Trees."

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French). In the spring of 1931 a number of seedlings were crossed and selfed to get an F_2 generation. Very few fruits were obtained because of unfavorable weather conditions following the hand pollinations.

The study of tree and fruit characters of the seedlings was continued. The results are in agreement with the statements made last year.

Several times during the winter the temperature fell below enough to kill some of the fruit buds. Part of the seedling orchard experienced a temperature of −18° F. Some of the fruit buds survived. More time, therefore, was given to determining the percentage of buds killed under outside conditions and less time to work with the freezing apparatus.

Testing Methods of Pruning. (J. K. Shaw). This project with young bearing apple trees has been continued as usual. No new developments have appeared. Under the conditions of this test no marked benefits from pruning are apparent. This should not be interpreted as meaning that bearing trees need not be pruned. Under conditions of good orchard management light pruning is probably desirable, but heavy or even moderate pruning seems to interfere with maximum production with no very distinct improvement in quality.

Effect of Pruning Bearing Apple Trees. (W. L. Cutler). The fifth year of this experiment in an orchard over forty years old was continued with no new trends appearing. This was the off-bearing year, and the crop was less than one-half of that of 1930 and somewhat scattered among the different varieties and trees.

This orchard was originally used as a test of different fertilizers and contained one plot which had received no fertilizer. In 1925 this plot was in very poor condition and since then it has received nitrate of soda at the rate of 500 or 300 pounds per acre. It is interesting to note that these trees have steadily improved in vigor, and for the past two years the crop has compared favorably with that of the fertilized plots, considering that the trees are considerably smaller.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw). This experiment has continued as modified in 1927. The sod plot receiving potash in addition to nitrogen continues to give an apparently larger yield of McIntosh and possibly of Baldwins than the companion plot receiving only nitrogen. The sod plot receiving 500 pounds per acre of nitrate of soda continues to yield slightly better than the plot receiving only 300 pounds. The cultivated plot with 300 pounds per acre of nitrate yielded more in 1931 than the plot without nitrogen, but not such a remarkable excess as in earlier years.

It seems doubtful whether an orchard can be maintained in sod so as to give maximum yields, even with rather liberal applications of nitrogen.

The orchard formerly used in a study of head formation in apple trees is now used for a fertilizer test, and regarded as a part of this project. Three of the seven plots received no fertilizer from planting to 1931, while the other four received nitrate of soda at the rate of 200 pounds per acre beginning in 1925. Beginning in 1931 two of the unfertilized plots received nitrate at the rate of 300 pounds per acre applied in the fall, while two of the nitrate plots received muriate of potash in the spring at the rate of 200 pounds per acre. There are no indications that potash has increased yields, while the fall nitrogen applications after the harvest could not influence the crop in 1931. The nitrogen plots yielded between two and three times as much as the plots which never have received nitrogen.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw). This orchard was limed in the spring of 1931 and the fertilizer treatments continued as before. White clover continues to prevail in the potash-phosphorus-lime plots, but the yields in 1931 were only about one-half those of the complete fertilizer plots. The percentage of fruit dropping was, as last year, larger on the complete fertilizer plots.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw). This project has been modified by applying the fertilizer only in the non-bearing year. This calls for omitting fertilizer in the spring of 1932. Yields continue to be larger with larger amounts of nitrogen.

Comparison of Cultivation and Heavy Mulching for Apples and Pears. (J. K. Shaw). Most of the pear trees have been removed from this orchard. Since it is apparent that cultivation without nitrogenous fertilizers is not a wise orchard practice, the cultivated plots received nitrate of soda at the rate of 300 pounds per acre beginning in 1931. The McIntosh trees have apparently responded to this treatment, giving the largest yield of any year except in the heavy crop year of 1930. The Wealthy trees have given a less distinct response but the crop was very small, this being the off-bearing year.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw). The old "soil test" field was replanted in the spring of 1931 with own-rooted

McIntosh and Wealthy apple trees. Care was taken to have the trees on the several plots of the same average size, though the individual trees showed some differences owing to variation among the trees available. With one or two exceptions the trees started and made good growth. The fertilizer treatment on Plot 11 was changed to 8 pounds superphosphate, 5½ pounds muriate of potash and 8 pounds nitrophoska and that of Plot 13 to 14½ pounds superphosphate, 8 pounds muriate of potash and 12 pounds of tankage. The fertilizer treatment of all other plots was continued as in previous years.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw). This study by means of pot cultures was continued. The use of sulfur to acidify soil from the potash-phosphorus-lime plot proved very injurious to the trees. Lowering the pH value to 4.0 or less apparently prevented nitrification and nearly or quite prevented growth of the seedling peach trees used as indicators. Aluminum sulfate used for the same purpose had little effect. Nitrogen carriers other than nitrate of soda favored growth. These included ammonium sulfate, urea, calurea, blood, fish, and cottonseed meal. Lime favored growth as in previous years.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw). This project is carried on in a sod orchard of Wealthy trees planted in 1915. It was planned to throw light on several questions that are of interest to fruit growers, the most important of which were the value of the addition of potash and phosphorus to nitrogen, and the value of lime as a supplement to the different mixtures used. As the trees tend strongly to biennial bearing, some trees bearing heavily one year and some the other, the yields must be considered in two-year periods.

It was assumed that in this orchard nitrogen was necessary. The question whether potash added to nitrogen increased the yield is not yet positively answered. Half of the plots were limed and half were unlimed. The unlimed plots averaged 8 per cent more than the limed plots in 1930-1931. The nitrogen plots yielded about one-third more than the plots without nitrogen, while with the 1928-1929 crops the increase was about one-fifth. This suggests the probability of increasing differences in later years.

The potash and phosphorus plots yielded moderately heavy crops and there is reason to believe that on this soil such a fertilizer is better than none. The average plot yield per tree varied from 382 pounds to 855 pounds. It is evident that factors other than fertilizer treatment are responsible for the larger differences in yield.

Study of Varieties of Tree Fruits. (J. K. Shaw and O. C. Roberts). This project has been broadened to include small fruits as well as tree fruits. It is impossible to say with accuracy just what varieties are "new." We have the following numbers of varieties which we consider may be called new: apples, 59; peaches and nectarines, 33; pears, 5; plums, 11; cherries, 8; grapes, 20; blackberries, 9; raspberries, 20; blueberries, 16; strawberries, 16. Most of these varieties will doubtless prove of no value, but among them are probably a very few that will rise to considerable commercial importance.

Among the new varieties of apples are about a dozen red-fruited variants from well-known varieties. Some of these promise well; others are little better than the older varieties. There are several distinct sports of Gravenstein among which the one originating in Washington and distributed by the New York Fruit Testing Association seems superior. Starking and Richared seem to be more desirable than Delicious. It is not known that Gallia Beauty is a bud

sport of Rome, but we have been unable to distinguish between trees of these two varieties. Gallia Beauty seems like Rome in fruit and superior in color to both Rome and Red Rome. We now believe that there may be two "strains" of McIntosh, one of which shows striping while the other does not. Usually one is nearly, or quite, as well colored as the other. Red Spy is more red than Northern Spy, but it is not much more attractive in appearance than well-colored specimens of Northern Spy. Red Duchess is but little better in color than Oldenburg.

Golden Delicious is too much inclined to be russeted and to wilt in storage to be desirable for planting here. It bears at an early age, produces well and is of high quality. It may be worth planting for a special market. Macoun continues to give promise and is well worth extended trial.

The New Jersey peach varieties continue to promise well and will in time replace most of our present early and mid-season varieties.

Portland is a promising early white grape. Among new raspberries, Lloyd George produces large berries of good quality, a few being produced in the fall. Thus far it has been resistant to mosaic. Newburgh continues promising; its greatest fault is that it is very thorny, making picking somewhat unpleasant.

The Howard 25 strawberry which we have tested for several years has been introduced to the trade as Howard Supreme and is now available to strawberry growers. It has been very productive, exceeding Howard 17 (Premier) during the past five years as follows: 28, 50, 15, 98, and 58 per cent. It should be remembered that these figures represent small plots in the vicinity of its place of origin. It remains to be seen whether it will maintain this high productiveness under extensive commercial tests. It is an imperfect or pistillate variety.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter). This project was started in the spring of 1928 to study the effect of the supply of soil nitrates on fruit-bud formation and fruit production. Nine fertilizer treatments are involved, each replicated five times on plots of thirty plants each. Runner plants were removed.

There were applied to each plot two pounds of a mixture of 200 pounds of superphosphate and 50 pounds of muriate of potash. This was worked into the soil after the plants were set.

Differential treatments to the 1931 plots were as follows:

1—No nitrogen.
2—August 17, nitrate of soda.
3—August 17, sulfate of ammonia.
4—August 17, calurea.
5—September 15, nitrate of soda.
6—September 15, sulfate of ammonia.
7—September 15, calurea.
8—October 19, sulfate of ammonia.
9—To be applied in spring, sulfate of ammonia.

The treatments have made no apparent differences in plant growth during the first summer.

Bud Mutations. (W. H. Thies). The selections from bud sport limbs have made good growth, but it will be several years before they all reach fruiting age.

Light Pruning of Young Grapevines. (B. D. Drain). This project was discontinued, following the resignation of Prof. Drain. The work indicated possibilities of greater leaf area and heavier production on vines lightly pruned

with thinning of the blossom clusters, as compared with the heavy pruning usually given grapevines.

Storage of McIntosh Apples Under Various Conditions. (O. C. Roberts cooperating with C. I. Gunness and W. R. Cole). This work has been continued in much the same manner as reported one year ago, with a few changes and additions as stated in the report of the Department of Agricultural Engineering.

Study of Various Spray Materials. (O. C. Roberts cooperating with A. I. Bourne). This year certain spray materials were given further field tests, and a few materials not tested previously were included. A summary of this project is contained in the report of the Department of Entomology.

Blueberry Culture. (J. S. Bailey). Propagation work has continued with increased success. Five box frames, as described by Johnston of Michigan, were constructed and proved very satisfactory for this work. The rooting of dormant cuttings taken in the spring was more successful than the rooting of green-wood cuttings taken in the summer. Granulated imported peat was used as the propagating medium. A preliminary experiment on the application of a complete nutrient solution to the rooted cutting in the propagating beds gave promising results. About 5000 cuttings of several varieties were rooted.

Cross Pollination and Sterility Studies with Certain Apple Varieties. (F. C. Sears, O. C. Roberts and others). The work on pollination of apples was continued with the following varieties: McIntosh, Cortland, and Northern Spy.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays). Non-broody and intense broody lines have been continued. The plan is to develop both lines for genetic similarity, except for the genes concerned with broodiness and with the intensity of broodiness. The non-broody generation hatched in 1930 consisted of 36 birds. Of this number 29 or 80.56 per cent were non-broody during the first laying year and averaged 227 eggs. The 7 broody birds in this line averaged 192 eggs. The intense-broody line of 1930 consisted of 23 birds and was 100 per cent broody. The mean egg record of this line was 180.

Data indicate that degree of broodiness is inherited. In general, a high degree of broodiness seems to dominate a low degree of broodiness in crosses.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn). Early sexual maturity and high persistency are the most uniform inherited characteristics in the flock. Intensity is high in the flock as a whole, but the variability in families is high. Special attention is being given to matings to secure greater uniformity for high intensity. The percentage of broodiness in this flock does not exceed 10 per cent.

Special attention is being given to improving egg size without sacrificing desirable fecundity traits. There has been an increase in egg size, but the mean annual production for the last flock was only 206 eggs. Vigor, as measured by mortality rate in the laying houses, has been improved and hatchability is constantly increasing.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn). Complete data on the cost of raising pedigree pullets and cockerels to 162 days of age were collected on the Station flock and reported in Poultry Science, May, 1931. All data on time required to reach standard egg weight have been tabulated for use. Data on types of intensity and on persistency have been prepared for publication.

A Genetic Study of Rhode Island Red Color. (F. A. Hays). Birds bred for standard qualifications above gave an average annual production of 130 eggs. Those selected for color from the production strain averaged 196 eggs. First-generation females produced by crossing high-fecundity females with a standard-bred male exhibited early sexual maturity, high intensity, and high persistency, further substantiating the dominance of these traits. Broodiness was increased to 55 per cent. The mean annual egg record of this first generation was about 195.

In plumage color the first generation cross is intermediate between the parent color. There is, however, a considerable range in plumage color. The effects of heterosis were shown by increased body weight.

Determination of Genetic Laws Governing Results of Inbreeding. (F. A. Hays). Mating father on daughters resulted in a marked decrease in annual production as compared with the parental stock. The mean egg record of the inbreds was 180 eggs while that of the parental stock was well above 200 eggs. The second generation produced by half brother-sister matings is not promising.

Hereditary and Environmental Characteristics Affecting Variability in Egg Production. (F. A. Hays). This experiment has been concluded with the generation hatched in 1930. Results will be published in the near future.

Factors Affecting Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays). Three lines are being developed based on the ability of the females to lay 52-gram, 57-gram and 59-gram eggs, respectively, in the month of December. The fourth generation was hatched in 1931. The data so far substantiate the proposed theory that gene A for small eggs is epistatic to gene B for large eggs.

Relation of Intensity or Rate of Laying to Feather Pigmentation. (F. A. Hays). This project terminates with the generation hatched in 1930. Data are being prepared for publication.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Elimination Law. (H. Van Roekel, K. L. Bullis, O. S. Flint, and Miriam K. Clarke). During the 1930-31 season, 402,983 blood samples, representing 356,810 chickens in 447 flocks, were tested for pullorum disease. Compared with the previous season, increases were observed in the number of tests and the number of tested birds. The average percentage of infection was 1.47, the lowest attained in eleven seasons. The number of birds in 100 per cent tested, non-reacting flocks increased. Infection was found in 26 flocks which were non-reacting in 1929-30. The reported possible sources of infection were failures to observe sound eradication measures. No reactors were detected among 2,099 fowl other than chickens.

A three-day conference for poultry disease laboratory workers of the Eastern States was sponsored by this laboratory. Thirteen states and two Canadian Provinces were represented. Pullorum disease, coccidiosis, and infectious laryngotracheitis were discussed. The purpose of this conference was to solve poultry disease problems and to standardize and adopt uniform, sound methods which will prove practical and effective in control or eradication.

Pullorum Disease Investigations. (H. Van Roekel, K. L. Bullis, O. S. Flint, and Miriam K. Clarke).

1. Twenty hens negative to the tube agglutination test were allowed to range on soil contaminated with droppings collected each week from reacting hens. Two yards, approximately 8 x 12 feet, were used alternately for periods of six weeks. At the end of the first six weeks, twelve birds were added to the flock. All hens continued to be negative to the agglutination test. Twelve birds died during the course of the investigation and at the end of 24 weeks, the remaining birds were necropsied. *S. pullorum* was not isolated from these 32 birds.

2. Twenty-four non-reacting pullets (eight weeks old) from a pullorum disease free flock were placed with twenty-four reacting pullets (nine to thirteen weeks of age) from an infected flock. The two groups were kept together until sexual maturity was attained. The non-reacting pullets remained negative for 111 days while in contact with the reactors, and for 70 days after the reactors had been removed.

3. Five hens and seven pullets negative to the tube agglutination test were fed fresh eggs laid by pullorum-infected hens. All birds were fed a minimum of 30 feedings and one received as many as 65. Each bird received one egg per day and was tested at frequent intervals. All birds were necropsied one month after the last feeding with the exception of one which died of a septicemic form of the disease 14 days after the last feeding. Two hens, including the fatal septicemic case, became definitely infected as indicated by agglutinins in the blood stream and the recovery of *S. pullorum* at necropsy. In two pullets, agglutinins were produced but *S. pullorum* was not isolated.

4. The testing of naturally and artificially infected chicks revealed that agglutinins were first detected between the ages of three and four weeks. Among chicks artificially infected and first tested at the age of four weeks, all infected individuals were detected as reactors before twelve weeks of age. Some reactors detected during this age interval later became negative. *S. pullorum* was isolated from chicks four to eight weeks old whose sera did not agglutinate pullorum antigen.

5. Pullorum infection was not established in pigeons when a suspension of the organism was fed to two pigeons and instilled into the eyes of two others for a period of six weeks. The birds were negative according to the tube agglutination test and on necropsy *S. pullorum* was not isolated. Three additional pigeons were inoculated intraperitoneally. Clinical manifestations of the disease and agglutinin production were observed. The disappearance of agglutinins was rapid and on necropsy *S. pullorum* was not recovered.

6. Sparrows appear to be susceptible to pullorum disease, as demonstrated by subcutaneous and intraperitoneal inoculations, by instillation into the eye, by forced feeding, and by exposure to contaminated feed and litter. Characteristic gross lesions of pullorum infection were observed and *S. pullorum* was recovered.

7. Concentrated pullorum antigen stored at 8° C. was tested at frequent intervals. The comparisons with freshly prepared antigens revealed that the antigenic properties were not affected at the age of 64 weeks.

8. Dilute pullorum antigen was divided into three equal parts. One part was titrated to pH 8.4, one part to pH 7.2, and one part to pH 7.2, but raised to Hp 8.4 at the time of each test. The antigens were stored at 8° C. and tested at frequent intervals with five positive and five negative pullorum sera. Consistent macroscopic antigenic differences were not observed among the antigens over a period of fifteen weeks.

9. Antigens were prepared monthly from three sets of cultures over a period of 45 weeks. Two sets of cultures were transferred at monthly intervals, one being retained at 8° C. and the other at room temperature (approximately 22° C.). The third set was transferred at weekly intervals and retained at room temperature. Comparative tests of these antigens during this period revealed no consistent antigenic macroscopic differences.

10. *S. pullorum* was observed to remain viable on a dry piece of cloth in a Kolle flask for 26 weeks. The viability observations are being continued.

Laboratory Service—Pathology. (G. L. Dunlap). This service was used by 311 persons, 92 of whom called either to deliver specimens or to discuss poultry diseases. A total of 1,046 specimens was received. Parasitic infestations continue to be the most frequent diseased conditions sent to the laboratory. Avian tuberculosis, fowl cholera, and fowl typhoid were not encountered this year. Carbon monoxide poisoning was diagnosed in two lots of chicks.

B. aerytrycke infection has been found in a number of pigeon lofts and an attempt is being made to eradicate the disease in one loft by means of the agglutination test.

A study was made of so-called "crazy chicks." The uric acid content of the blood of affected chicks was found to be two to six times greater than normal. Epithelial degeneration of the kidney and proventriculus was the prominent lesion. Details of this work were presented at the annual meeting of the American Veterinary Medical Association (Kansas City, August, 1931) as Massachusetts Agricultural Experiment Station Contribution 125, "An Ataxia of Chicks Associated with Nephritis."

The causes of mortality in the Station flock are being studied in an effort to minimize these losses.

Farm and Station Bang's Disease. The laboratory, in assisting this project, has recorded 966 agglutination tests.

Infectious Laryngotracheitis. (C. S. Gibbs). Studies on chronic carriers of infectious laryngotracheitis in poultry have been continued. Among 520 birds examined by direct swabbing of the trachea, 17 chronic carriers have been found. The longest time a carrier eliminated virus was 378 days and the shortest time was 14 days. Three of the chronic carriers have not yet completed the carrier stage. Thirteen may be classified as constant and four as intermittent in type. A more expedient test to detect chronic carriers is needed.

Studies indicate that the most common channel of infection is the respiratory tract.

Pullets and cockerels, as well as adult birds, may be immunized by intravenous and subcutaneous inoculations of small doses of filtered virus over a long period of time. No practical method for immunization of birds on a large scale is recommended.

Moldy Corn. (C. S. Gibbs). The feeding of moldy corn did not produce watery eyes or laryngotracheal symptoms, as has been reported. Severe intestinal reactions occurred in all of the chickens when first placed on the moldy corn ration, and one died of enteritis. After feeding on moldy corn continuously for four weeks, the chickens apparently developed a tolerance and did not show any further ill effects.

Infectious Bronchitis. (C. S. Gibbs). A streptococcus has been found in baby chicks apparently responsible for an epizootic with symptoms resembling infectious laryngotracheitis. The microorganism is a new species and attacks the bronchial tubes of baby chicks. This disease should be called infectious bronchitis, and it should not be confused pathologically with infectious laryngotracheitis, which is due to a filtrable virus.

Avian Paralysis. (C. S. Gibbs and G. L. Dunlap). A limited study of avian paralysis has been made. Nutritional, parasitic, and neoplastic types have been recognized. These three types are distinct entities. The first two forms are preventable and sometimes curable. The neoplastic form of paralysis is not so well understood and presents a real problem to poultrymen and pathologists. Our studies have been confined largely to this type and are being conducted along two lines.

1. Two groups of breeding fowls have been selected for mating to determine if the disease is transmitted through the egg. One group of these fowls has a definite history of paralysis, while the history of the other is free of the disease. One hundred and ninety-nine chickens hatched from these matings are under observation.

2. Sixty-four chicks have been inoculated by different methods, using neoplastic tissues from affected fowls to determine if this material is infectious. Some of these birds are still under observation.

THE WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon in Charge

The research work of this Station has been conducted principally along the same lines as in 1930. As rapidly as results have been obtained they have been released to the commercial growers for application to their problems, without waiting until the completion of the entire project.

The use of the Station as a center of practice demonstrations and as a bureau of horticultural information has shown a marked increase. During the year 1400 persons visited the Station seeking individual assistance from members of the staff; Field Day attracted 860 more; the attendance at the School for Commercial Florists was 140; and 657 registered at the School for Home Gardeners. Thus the Station has served some 3000 visitors who have come for one reason or another. Telephone queries have numbered 1315, and 2450 letters (not circular) have gone out in answer to requests for information.

A strong interest has been manifested by the commercial nurserymen in having the Experiment Station institute investigations in their behalf at the Waltham Station. A bill for an appropriation to provide for this work is in the process of drafting and will be presented to the legislature during the session of 1932.

For reports on experiments conducted at this Station, in addition to those listed under this caption, see report of the Departments of Botany, Entomology and Floriculture.

The Plant House. (P. W. Dempsey). Interest on the part of growers in this superior method for growing plants continues. A new set of plans including some improvements over the original plant house has been mimeographed, for the purpose of mailing in response to definite requests. Since this project was started in 1928, some 2000 copies of plans and specifications have been distributed throughout New England, and many visitors have come to the Field Station with the sole idea of looking over the model plant house which has been erected here.

Electricity as a Source of Heat in the Hotbed and Propagating Bench. (P. W. Dempsey). Three hotbeds of four sash each were operated in the early spring to determine the comparative merits of manure, hot water and electricity as sources of heat. Considering both the cost and the results obtained, electricity at 5 cents or less per kilowatt hour is entirely practical for the grower using less than fifteen sash. The commercial production at a fair price of a practical lead-covered, almost foolproof, heating cable and a reliable thermostat makes this new method of heating hotbeds available to the grower. Work will be continued to gain more essential knowledge along this line. A mimeographed set of plans and specifications was made in the late spring and over 200 copies have been distributed in response to requests for information.

The same equipment, cable and thermostat can be used as a source of bottom heat in the propagating bench and elsewhere in the greenhouse. Last winter considerable work was done using strip heaters, coiled resistance wire, and other heating elements, but all of these became decidedly antiquated upon the introduction of the lead-covered cable in February of this year. At present, December, 1931, there are being maintained five different temperatures under carnations, four different temperatures in the propagating bench, and a heating cable under two rows of cucumbers providing a differential af 10° F.

Most of this work is done in cooperation with the Edison Electric Illuminating Company of Boston and the General Electric Company.

Vegetable Variety Trials. (P. W. Dempsey). Forty varieties and strains of lettuce were planted at various times during the season. The so-called "White Big Boston" variety continued to show outstanding qualities that make it worthy of trial by lettuce growers. For three years unsatisfactory results have been obtained from many strains of the Black Seeded Tennis Ball type. From similar reports made by growers it would seem that this variety may be going to pieces. We have been recommending it for years as the standard head lettuce variety. Next year we are planning a thorough study of the Black Seeded Tennis Ball and White Big Boston varieties.

Fifty-two strains and varieties of sweet corn were planted at two different dates. Spanish Gold, a new introduction from Dr. Jones of Connecticut, showed up exceptionally well as a high yielding early yellow corn. Golden Gem as the earliest yellow corn of fair size and good quality, and Golden Sunshine as a standard variety to replace Golden Bantam continued to show great promise for the future.

Forty strains and varieties of beets were seeded in two plantings. The variety names Crosby Egyptian and Early Wonder are practically synonymous.

The several strains of each variety tested for the past four years show decided similarity in all characteristics. Dark strains of Crosby Egyptian are being featured by seedsmen, their only difference from the old type being in the elimination of the light zones showing so plainly on a cross section of most strains of this popular variety.

Twenty-three varieties and strains of tomatoes were planted, half of the number of plants of each strain being staked and the other half grown flat. The new variety Break O' Day introduced by the U. S. D. A. did not show up well in our trials. It was not as early as described in comparison with other varieties; the plants were uneven in maturity and type of growth; and the fruit was uneven in shape, size, and color. Bison and Progress, two new varieties from North Dakota, proved unsatisfactory since most of the fruit was of exceptionally poor shape. After four years in our trials we have decided not to include the Burbank variety again. From our results it appears to be a poor strain of Earliana.

Asparagus Investigations. (Robert E. Young).

Fertilizers. Two of the three series of asparagus fertilizer plots planted in 1928 were cut for the first time this season. The growth of the asparagus on the Concord plots was so small that the cutting of any spears would have permanently injured the bed. The beds at Waltham and Eastham were cut for a period of two weeks each. Because of the short cutting period, the yield records cannot be interpreted to the extent of saying that any one fertilizer treatment was better than another. There was a wider spread in yields between duplicate plots with the same treatment than between different treatments.

The pH determinations have been made on all of the plots to determine the effect of the different fertilizer combinations on the soil reaction. In all three experiments, organic fertilizers such as fish, guano, cottonseed meal and goat manure had a marked tendency to make the soil acid. The depression of the pH was as much as two points in some instances. The application of ammonium sulfate did not have the same effect on the pH on all plots. On the sandy soil on the Cape this fertilizer did not affect the soil reaction to a very marked extent except on the acid soil. On these plots the growth was less than half as high as on the surrounding plots, and the stand had decreased 50 per cent. On the Waltham plots, sulfate of ammonia did not affect the soil reaction very significantly.

The growth of the asparagus on the plots at Eastham has varied quite widely. Before the asparagus was planted, one-half of this land had a crop of carrots that was not harvested but plowed under; a large crop of turnips was harvested from the other half. The asparagus plots located on the soil which had previously grown the carrots produced a much larger yield than did the other plots. The line of demarcation was plainly visible throughout the growing season. The yield records from these plots show that the most important factor in the growth of asparagus in the Merrimac coarse sand, which is typical of the soil on Cape Cod, is the supply of organic matter in the soil.

Depth of Planting and Height of Cutting. The cutting season for these plots was the full period of six weeks. The records for the cutting show that the more green that is allowed to develop (8 inches to 12 inches), the more pounds of asparagus may be removed per acre. There was no significant difference in yield per plant of asparagus planted at the various depths; but there was a wide variation in the mortality of plants planted at the various depths, as is shown by the following table.

Depth of planting Inches	Plants alive Per cent
2	89
4	87
6	81
8	70

This reduction in the number of plants would decrease the yield per acre to a very marked extent.

Seed Improvement. (Robert E. Young, Waltham). Selections were made from eight F_2 strains of Blue Hubbard Squash. Some of the strains show promise of being high yielders and of high quality, but these strains are not the shape that is desired by our market. Crosses have been made with other strains to obtain the desired shape. Dry matter was determined on many squashes and some variations were found. Some selections will be made on this basis to try to obtain dry type squash.

Selections were continued on twenty strains of Horticultural Beans. The beans from a few of the strains showed the color desired by our market. Studies are being continued in the greenhouse to determine the factors affecting coloration of the bean pods.

The sport of Oshkosh pepper that has been grown at the Waltham Field Station for some time has been found to set well under the adverse conditions sometimes found around Boston. This pepper produces fruits that are varied in shape and not very desirable for green peppers. Selections and crosses are being made to improve this condition.

Selections are being continued on the Bel-May Lettuce to keep up the foundation stock.

Selections on the Wyman Crosby Beet were continued for both shape and zoning, in an attempt to improve the foundation stock of this beet.

The foundation stock of the Hutchinson Carrot is being maintained. One thousand pounds of seed were produced in California for distribution in 1932.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station. C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger). In 1930 sixteen different strains of Havana Seed tobacco were grown in the field in an attempt to find, if possible, strains that, under Connecticut Valley conditions, are satisfactory for resistance to black root-rot, for type of plant, for type and quality of leaf, and for producing capacity. Four of these were strains of Havana Seed commonly grown in the Connecticut Valley, known to be acceptable for type of plant and type and quality of leaf, and used as standards of comparison in these respects. One strain was Havana 142A3, known to be satisfactorily resistant to black root-rot, and used as a standard of comparison in this respect. Eleven strains were new strains of Havana Seed whose properties had never been determined under Connecticut Valley conditions.

In these tests, none of the more common strains of Havana Seed showed satisfactory resistance to black root-rot as strains, nor was it possible to select

individual plants within these strains which seemed to be satisfactorily resistant Eight of the new strains seemed to be approximately as resistant to black root-. rot as Havana 142A3, as determined by comparision of producng capacities and infections of black root-rot when grown in soil which was heavily infested with *Thielavia basicola*.

The producing capacity of the four common strains, of Havana 142A3, and of these eight new strains, as indicated by the yields in 1930 on soil free or nearly free of *Thielavia basicola*, are shown in the following table:

	Yields per Acre Pounds	Grade Index Values
Havana Seed—common strains	1818	.458
	1908	.436
	1769	.445
	1879	.438
Havana 142A3	2083	.491
Havana Seed—new strains	1984	.453
	2111	.505
	2015	.496
	1996	.492
	1987	.493
	2031	.528
	1897	.491
	1897	.490

Eight of the eleven new strains were satisfactory for resistance to black root-rot and for yielding capacity; but one of these eight was definitely unsatisfactory for type of plant and type and quality of leaf, and for this reason was discontinued. Thus far it appears that seven of the new strains of Havana Seed may be acceptable for resistance to black root-rot, type of plant, type and quality of leaf, and yielding capacity. These deserve further testing.

Mosaic. (C. V. Kightlinger). It has been determined experimentally that tobacco mosaic virus, contained within tobacco debris mixed with moist sandy loam soil, clay soil, or sandy soil and kept under out-of-doors conditions except for leaching, in each case retained its viability for two seasons sufficiently to produce infections of mosaic when suspensions of such mixtures of soil and debris were inoculated into healthy tobacco plants by the needle method.

In inoculation tests by the needle method, it has been found that formaldehyde, acetic acid, and several other substances, when mixed directly with the expressed juices of mosaic-diseased tobacco plants, were able to inactivate the virus sufficiently to prevent infections. Whether these chemicals, when used as seedbed disinfectants in the usual manner and in the usual amounts and concentrations, may be able to inactivate the mosaic viruses contained in seedbed soil, has not been definitely determined. Preparations have been made for final tests of this point, and the actual tests will be made next spring and summer.

PUBLICATIONS

Bulletins

270 Meteorological Records—A Forty-Year Summary, 1889-1928. C. I. Gunness. 20 pp. December, 1930.

This is a monthly summary of records kept at this institution since the work was started in 1889. The position of the observatory is given, with enough information about the instruments used to enable the reader to interpret the records.

271 Annual Report for the Fiscal Year Ending November 30, 1930. 64 pp. February, 1931.

The main purpose of this report is to provide an opportunity for presenting, in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

272 Experiments with Hedges. Frank A. Waugh. 24 pp. March, 1931.

Hedges are coming back into fashion. They always were both useful and beautiful when properly placed and well kept. They serve as boundaries on property lines, as enclosures to gardens, as windbreaks, and for privacy in the home grounds. Many species of trees and shrubs will make good hedges under suitable management. This fact gives range for critical choice of materials. The Department of Landscape Architecture, Massachusetts State College, has maintained a demonstration and experimental garden for testing hedges for ten years, and this bulletin is a report of that work.

273 Infectious Trachitis. Charles S. Gibbs. 32 pp. April, 1931.

Infectious trachitis has been the cause of heavy losses to the poultry industry in the State of Massachusetts. Evidences are apparent that these losses are increasing, and there is a pronounced interest in methods of prevention and control. This study of the disease, its symptoms, pathology and mode of transmission, was undertaken to furnish a basis for procedure in perfecting control methods. (Technical).

274 The Identification of Apple Varieties from Non-Bearing Trees. J. K. Shaw and A. P. French. 32 pp. April, 1931.

Much of the disappointment and financial loss caused by planting misnamed trees could be avoided if varieties were known as young trees in the nursery, or even if misnamed trees were detected soon after planting in the orchard. Varieties of apples can be recognized by tree and leaf characters as easily and surely as by the characters of the fruit. This bulletin discusses and illustrates some of these characters.

275 Planning the Farm Business on Three Dairy-Fruit Farms in Massachusetts. R. L. Mighell. 28 pp. June, 1931.

Farm adjustments made by individual farmers often serve as valuable guides to others in similar situations. This study presents an analysis of some common types of problems for which solutions have been found to fit in these particular cases. Exactly the same adjustments might not fit other farms. They may, however, serve as suggestions to other farmers in like situations.

276 Increasing Soil Acidity as a Means of Controlling Black Root-Rot of Tobacco. William L. Doran.. 30 pp June, 1931.

Soil with a pH value of about 5.9 or higher are favorable to the growth of the fungus which causes black root-rot and are therefore unsafe for tobacco. The primary object of the work here described was to study means of lowering the pH value of soil infested with *Thielavia basicola*, and thereby decreasing the loss caused by black root-rot of tobacco.

277 Flower Pot Composition and Its Effect on Plant Growth. Linus H. Jones. 16 pp. October, 1931.

The ordinary flower pot of fired clay has been the standard plant container for many years. In recent years, however, flower pots of other materials have come on the market; and of these, paper pots have received most consideration because of their economic advan-

tages. A result of this interest has been a pronounced demand for reliable information concerning the comparative merits of different types of containers. The investigation reported in this bulletin was begun in response to this demand, and has given results which are applicable either to the production of greenhouse plants in wholesale quantities or to the growing of a single house plant.

278 Infectious Laryngotracheitis Carriers. Charles S. Gibbs. 12 pp. December, 1931.

The investigations on infectious laryngotracheitis for the past year at this Station have centered largely around carrier problems and control measures. While the goal has not been reached, important advances have been made, and the disease can now be handled under laboratory conditions more effectively than it was a year ago. The results contained in this paper are in no sense complete, but are published in the hope that poultrymen and others interested in the control of infectious laryngotracheitis may find in them some practical applications under field conditions.

279 Onion Spraying and Dusting Experiments. W. L. Doran and A. I. Bourne. 12 pp. December, 1931.

In 1927 and 1928 seed onions died prematurely in the Connecticut Valley of a disease here designated as blast. In earlier years, downy mildew of onions has also sometimes caused a reduction in yields. The field experiments here described were undertaken with the object of learning to what extent fungicides will protect onions against these diseases.

Control Bulletins

58 Eleventh Annual Report on Eradication of Pullorum Disease in Massachusetts. H. Van Roekel. 24 pp. May, 1931.

59 Inspection of Commercial Feedstuffs. Philip H. Smith. 49 pp. 1931.

60 Inspection of Commercial Fertilizers. H. D. Haskins. 50 pp. December, 1931.

61 Inspection of Agricultural Lime Products. H. D. Haskins and H. R. DeRose. 6 pp. December, 1931.

Meteorological Reports

505-516, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. C. I. Gunness.

Reports of Investigation in Journals
(Numbered Contributions)

108 Increase in Egg Weight during the Pullet Laying Year. F. A. Hays. Poultry Sci. Assoc. Proc. 1930.

109 Linkage Relations between Genes for Egg Size and Genes Concerned in High Fecundity in Domestic Fowl. Frank A. Hays. Proc. World's Poultry Congress, 1930:134-138.

110 Effect of the Structure and Moisture of Plant Containers on the Temperature of Their Soil Contents. Linus H. Jones. Jour. Agr. Research 42:375-378. March 15, 1931.

112 Calcium Requirements of Dairy Heifers. J. B. Lindsey, J. G. Archibald, and P. R. Nelson. Jour. Agr. Research 42:883-896. June 15, 1931.

113 Saprophytic and Secondary Microorganisms Occurring in the Respiratory Tracts of Domestic Fowls and Chickens in Health and Disease. Charles S. Gibbs. Jour. Bact. 21:97-109. February, 1931.

114 Packed Heat from a New Type of Electric Steam Generator. Howard Bidwell and Linus H. Jones. Indus. and Engin. Chem. 23: March, 1931.

115 Intensive Grassland Management. Richard C. Foley. Amer. Soc. Anim. Prod. Proc. 1930.

116 Further Evidence of a Potash-Lime Deficiency in a Sandy Loam Soil. J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 1930:12-14.

117 Recent Developments in Nursery Variety Certification. J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 1930:82-84.

118 Cost of Raising Pedigreed Pullets and Cockerels. F. A. Hays. Poultry Sci. 10:178-182. May 1, 1931.

119 The Relation of Temperature to Egg Production. J. C. Graham. Poultry Sci. Assoc. Proc. 1930.

120 The Assimilation of Nitrogen by Tobacco. A. B. Beaumont, G. J. Larsinos, P. Piekenbrock and P. R. Nelson. Jour. Agr. Research 43:559-567. September 15, 1931.

Other Contributions to Journals
(Unnumbered)

Study Proves Glass Superior Container for Growing Plants. L. H. Jones. The Glass Container 10(5):12-41. March, 1931.

Test Pots for House Plants. L. H. Jones. The Florists' Review (Chicago) 69 (1774):19-21. November 26, 1931.

Insect Pests of Massachusetts Orchards in 1930. A. I. Bourne. Mass. Fruit Growers' Assoc. Rpt. 1931.

Will Recommended Control Measures for Apple Maggot Work in Massachusetts? A. I. Bourne. Mass. Fruit Growers' Assoc. Rpt. 1931.

A Test of Certain Spray Materials. O. C. Roberts and A. I. Bourne. Mass. Fruit Growers' Assoc. Rpt. 1931.

Control of the Plum Curculio in Apple Orchards. W. D. Whitcomb. Conn. Pom. Soc. Rpt. December 1930.

The Curculio and the Weather. W. D. Whitcomb. Mass. Fruit Growers' Assoc. Rpt. 1931.

The Plum Curculio—An Apple Pest. W. D. Whitcomb. Fruits and Gardens 47:3-4. April, 1931.

Control of Root Weevils on Taxus and Other Nursery Plants. W. D. Whitcomb. Natl. Nurseryman 39:5-6. June, 1931.

Time—Temperature—Humidity Relations in Dried Fruit Pasteurization. J. A. Clague and C. R. Fellers. Jour. Bact. 20:30-31. January, 1931.

Preservation of Sweet Cider. C. R. Fellers. Fruit Products Jour. 10:333-335; 374-375. July and August, 1931.

CHANGES IN STAFF, DECEMBER 1, 1930, TO NOVEMBER 30, 1931

Appointments

Eisenmenger, Walter S., Ph.D., Research Professor in Agronomy, January 1, 1931.

Isham, Paul D., B. S., Fellow in Horticultural Manufactures, December 27, 1930.

Nagle, Margaret, Laboratory Assistant in Seed Law, February 1, 1931.

Thigpen, James E., B. S., Research Assistant in Farm Management, September 1, 1931.

Wait, Bernice C., Ph. D., Assistant Research Professor in Home Economics, September 22, 1931.

Young, Robert E., M. S., Assistant Research Professor in Vegetable Gardening, June 1, 1931.

Zimnoski, Felicia, Laboratory Assistant in Poultry Disease Control, September 1, 1931.

Resignations

Stuart, William M., M. S., Research Assistant in Agronomy, June 30, 1931.
Wright, Kenneth E., M. S., Assistant Research Professor in Dairying, September 15, 1931.

Deaths

Cutler, Walter L., Technical Assistant in Pomology, October 31, 1931.
Davies, Esther, Ph. B., Assistant Research Professor in Home Economics, July 12, 1931.

Publication of this Document Approved by Commission on Administration and Finance
2500-3-32. No. 1882.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 281 April, 1932

Experiments with Permanent Pastures

By A. B. Beaumont

A large proportion of the farm land of Massachusetts consists of stony uplands more suitable for permanent pastures than for tilled crops. The improvement of pastures by top-dressing with fertilizers offers attractive possibilities. Although there are certain discouraging conditions attending it, the goal is worth the effort; for the fact that large areas have already reverted to forest shows what must happen to existing pastures if fertilizer is not applied, or if the price of milk is too low to make such application profitable. A pasture which is weedy or run-down because of a lack of plant food can be brought back to productive condition only by the use of plant food.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

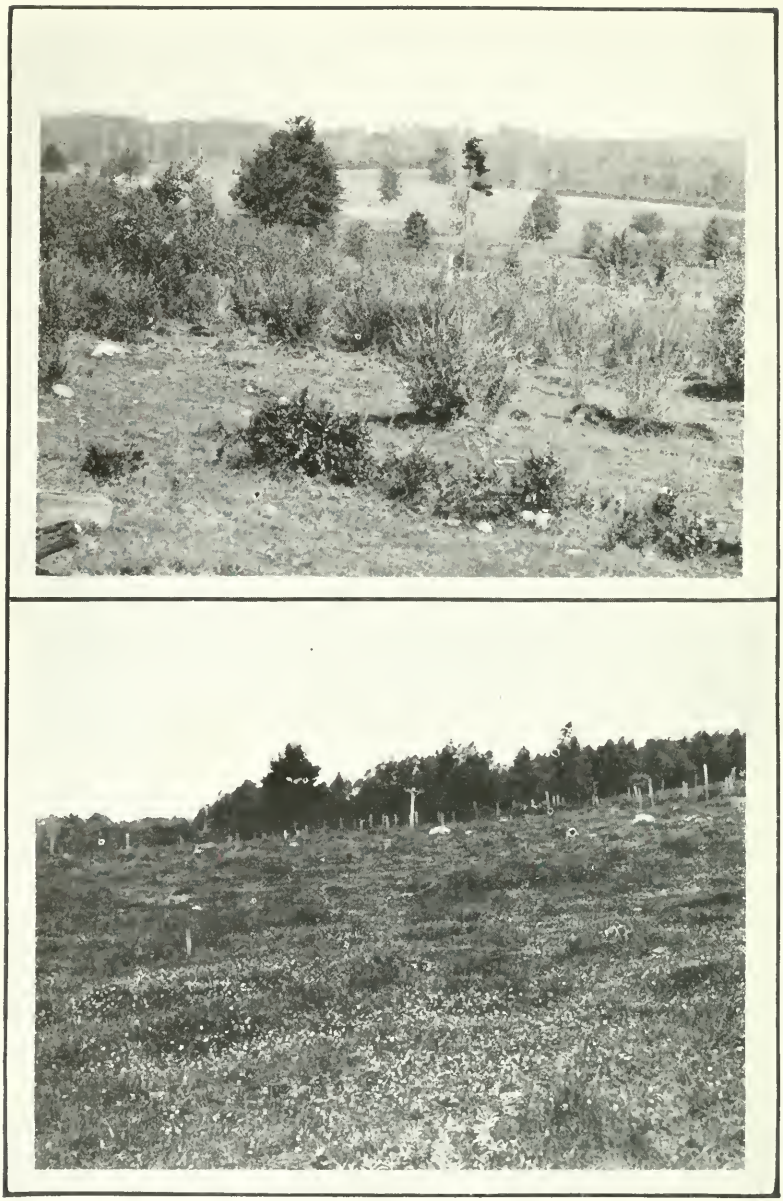

Fig. 1.—Only a fence separates this unimproved (upper) from the improved (lower) pasture. Both fields are in the immediate vicinity of experiments A and B described in this bulletin. Fertilizer and lime have been the principal factors in making the difference.

EXPERIMENTS WITH PERMANENT PASTURES

By A. B. Beaumont, Professor of Agronomy

INTRODUCTION

When the farmers of the early colonial period first began to turn their stock on the upland pastures of what is now the State of Massachusetts, they no doubt found good to excellent grazing conditions. This is a fair assumption, because practically all our present permanent pastures were originally wooded, and most wooded areas, on account of the accumulation of leaf mold and forest debris, are fertile for some years after clearing. It is well known that the productivity of Massachusetts upland pastures is now generally very low. Just when these pastures began to fail sufficiently to attract the attention of farmers is not clear from records now available. Very likely, on account of sparseness of settlement and constant clearing of new land, the pasture problem did not become serious until after the Revolutionary period. In any event, we find mention of this problem in the records of agricultural societies of seventy-five to one hundred years ago.

Charles L. Flint, (6) in an "Essay on Top Dressings for Mowings and Pasture Lands," wrote in 1850, "It is a matter of regret that the improvement of waste lands has not been treated in a manner which its importance deserves . . . . . The idea was formerly entertained that pasture lands were sufficiently enriched by the animals which fed them. Practical men begin to think otherwise." He advised the use on pastures of such top-dressing materials as were then available to the farmer, including meadow mud, peat mud, manure, lime, wood ashes, land plaster, bone dust, charcoal, compost. Another writer (12) of about the same period gives a rather accurate description of the condition of many Massachusetts pastures of that time in the following words: "The great want of the milk raisers and butter-makers at the present time, is the restoration to fertility of their exhausted pasture lands. There are thousands of acres . . . . . that formerly yielded good pasturage; they are covered with small bushes and mosses, and yield so little grass, that ten acres will scarcely keep a cow. Many of these pastures are rocky and hilly, and cannot be ploughed. . . . . We do not expect mowing lands without irrigation or top-dressing, to continue to yield crops for successive generations. Why should we expect it of pastures?"

From the middle of the last century on to the present time more or less frequent mention of the pasture problem is found in the literature. No doubt the acuteness of the New England pasture problem was deferred until comparatively recent years by tremendous development of the grain sections of the Middle and Far West. Imported grain concentrates were cheap, and they were fed by dairy farmers without stint. Thus there was no strong economic urge to improve pastures, and most New England farmers fell into the habit of regarding the pasture as one part of the farm which could look out for itself. It is only within the past decade or two that Massachusetts farmers have begun to think of the pasture herbage as a crop which will give returns for labor and fertilizer much as will hay, corn or any other crop.

The Pasture Problem

Massachusetts had a total population of 4,249,614 or 528.6 persons to the square mile, in 1930. With its large, compact urban population, with good roads and short distances, this State presents an ideal market for dairy products.

Residents of Massachusetts annually consume milk and cream valued at approximately $105,331,000 in 1929. Massachusetts farmers supplied milk and cream valued at $23,094,170, or about 22 per cent of the total.[1] Present prices are lower than those received in 1929, but the figures for the percentage of the total supplied hold approximately.

According to the 1930 census 753,088 acres, or 37.6 per cent of the total farm land, were classed as pasture in 1929. Of this amount 78.5 per cent was not plowable. For the same year the number of pasturable dairy animals was 184,369. From these figures it would appear that the average carrying capacity of Massachusetts pastures in 1929 was approximately ¼ cow per acre, but even this figure is generous because much supplementary barn feed was given cows on pasture. It is conservative to say that by the use of approved methods of pasture management, the carrying capacity of Massachusetts pastures can be doubled. With one of the best milk markets in the world, this is a point worth the careful consideration of Massachusetts dairy farmers.

In Massachusetts, as in other sections of the glaciated area of the northeastern United States, there are large areas of stony soils which on account of the preponderance of stones and a rough topography are unsuitable for tilled crops. Most of these soils have a fine-earth portion which ranges in texture from a loam to a sandy loam, and which is sufficiently retentive of moisture and in other respects suitable for pasture grasses and clovers. Such, for example, are the Gloucester soils, a series which in Worcester County makes up 29 per cent of the total land area. There are other soils in Massachusetts somewhat similar in these respects to the Gloucester series.

While much of the area of rough stony soils is in timber, and possibly some of the area now in pastures should revert to timber, it would seem wise to utilize a large portion of the stony soils of good texture for pastures. Forests, on the other hand, might be more extensively developed on the light, infertile, droughty outwash plains and on the roughest and most stony uplands. Massachusetts has much land of the latter types.

Aside from the question of the best use of various soil types, the main problem of the Massachusetts pasture is that of the character of the vegetation. In fact, the pasture problem of New England can be summed up in one word—weeds. By weeds are meant plants such as running cinquefoil, haircap moss, red sorrel, devil's paintbrush, hardhack and gray birch, found in, and too often dominating upland pastures. Plants in general reflect the fertility of the soil in which they grow, and the weeds mentioned generally indicate a low state of soil fertility.

The experiments covering a period of ten years reported in this bulletin show that the common herbaceous weeds of upland pastures can be displaced by nutritious pasture plants such as white clover, bent grasses, and Kentucky blue grass, by a judicious use of chemical fertilizers and lime, in addition to adequate grazing. Shrubby weeds, once cleared, can be kept under control by similar methods. Present low prices of fertilizer materials make this method of pasture improvement attractive.

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[1] Data from U. S. Census of 1930 and recent state surveys. Values are those received by farmers and are ½ to ⅔ prices paid by consumers. Although some butter is made from milk produced in Massachusetts, most of the butter consumed comes from outside the State, as does practically all the cheese.

Experiments in Pasture Improvement by Top-dressing

From time to time in years past many Massachusetts farmers have made tests of various methods and materials for the improvement of pastures. Some of the results of these tests as well as valuable observations were recorded in the Reports of the State Board of Agriculture, and they were a distinct contribution to our knowledge of pasture management. However, the first experiment in the use of modern chemical fertilizers undertaken by the Massachusetts Agricultural Experiment Station was the one laid out by Wm. P. Brooks in 1909, and continued until 1916. This experiment is described later.

During the period immediately following the World War, interest in pasture experiments was revived and a number of tests were made of chemical fertilizers applied as top-dressing to run-out pastures in the counties of western Massachusetts. These tests were conducted by the County Extension Service Agents of these counties, working in cooperation with the Extension Specialist of the Agronomy Department of the Massachusetts Agricultural College. In practically all the tests only lime and superphosphate were applied, singly or in combination. In some cases immediate and marked response was obtained from these materials; in others, benefits were slight or negligible. An outstanding example of response to soluble phosphoric acid was obtained in 1921-22 by J. B. Abbott, then Extension Agronomist, from an application of 16 per cent superphosphate at the rate of 2000 pounds to the acre on the Potter Farm at Great Barrington.

In the spring of 1921 the Massachusetts Experiment Station again took up the problem of pasture improvement by means of fertilizers. In the period 1921-1930 several experiments in the top-dressing of upland pastures were started, three of which are the main subject of this bulletin.

REVIEW OF LITERATURE

The revival of interest in pasture problems which has occurred in recent years is reflected in the increase of publications bearing on the subject. For example, for the three-year period of 1916-18, a total of 129 references to papers on pastures and meadows is listed in the Agricultural Index, whereas for the period 1928-30, 260 titles are listed.

It is not intended in this bulletin to give a complete review of the literature bearing on pastures, or even a complete review of that which bears on the question of top-dressing permanent pastures, the phase of the subject with which this report is especially concerned. Brown and Slate (4) have given an excellent and rather complete review of pasture literature in several of its phases, up to 1929. For a detailed review of the literature and bibliographies, the reader is referred to the bulletin of Brown and Slate, as well as to Vol. 21, No. 6 of the Journal of the American Society of Agronomy (1929), which contains the papers presented at a symposium on Pasture Management Research. The following review is intended to cover the principal publications bearing on the subject matter of this report and published since 1929.

Orr (10) has published a comprehensive treatise on the relation of minerals in pasture soils to the mineral content of the herbage and of this in turn to the health of the grazing animals. Many of the mineral-deficiency diseases of grazing animals are traceable to the mineral content of the soil, according to this author. He points out that scientific information already at hand warrants the belief that the production of the grazing lands of the world can be doubled and, at the same time, the health and quality of the grazing animals improved. "The

natural method of increasing the supply of minerals to the grazing animal is by enrichment of the pastures." An extensive bibliography is appended to Orr's book.

Ellenberger and others (5) show that there is considerable variation in the yield of unfertilized Vermont pastures. Total acre yields of dry clippings from 11 pastures varied from 261 to 4,031 pounds, and averaged 1748 pounds. Likewise, there was considerable variation in the percentage of crude protein and minerals from the different pastures. In general, the percentage of protein, calcium and phosphorus was higher in the grass from the better pastures.

Abbott (1) has reported the results of 103 tests of fertilizer chemicals applied as top-dressing to pastures in 15 northern states and Ontario. There was a wide variation in the response to lime, phosphorus, potassium, and nitrogen, but the results in general show benefits from both minerals and nitrogen.

Mortimer and Richards (8) have reported results from top-dressing permanent pastures situated on Miami silt loam at Madison, Wisconsin. Lime alone gave an increase of 15.6 per cent; lime and superphosphate, 42.6 per cent; and lime, superphosphate, and potash, 153.2 per cent. The effect of potash in encouraging the growth of white and alsike clovers was marked. Nitrogen alone or in connection with the minerals was only slightly effective.

Odland and others (9) have published results of pasture experiments conducted on Dekalb clay loam in West Virginia. Lime, superphosphate, and manure produced best results, followed in order by lime and manure, lime and superphosphate, superphosphate, nitrate of soda, and lime. Potash fertilizers were not used as such. Seeding experiments showed "conclusively that scattering seed over a pasture of this type without other treatment is useless. . . . . Like seeding, disking a pasture without other treatment cannot be expected to produce any benefits."

Recently, Prince and others (11) have published data from experiments in top-dressing old pastures in New Hampshire. Data from ten outlying experiments for one year are reported. Results in terms of pounds of protein per acre show a response to phosphorus, lime, and potash in 4 cases each, and response to nitrogen in 7 cases. It is pointed out that the greatest response to minerals was obtained on pastures originally having a fair or good stand of white clover, and the greatest response to nitrogen from those pastures which contained practically nothing but grass. Likewise, results from experiments made on 6 pastures in Vermont by Van Alstine and Cook (13) show response to lime in 3 cases, to phosphorus in 4 cases, to potash in 3 cases, and to nitrogen in 5 cases.

Summarizing the literature bearing particularly on the question of top-dressing permanent pastures, it may be stated:

1. Generally, lime has been shown to be the first limiting factor in the productivity of run-out permanent pastures of the Northeastern States.

2. Phosphorus has been found to be deficient in most of the pasture soils of this region.

3. Marked response to potassium has been reported from some experiments, but potassium has not been as generally deficient as phosphorus.

4. In most of the experiments reported there has been some response to applied nitrogen. This response has been greatest in case of pastures whose herbage consisted mainly of grasses, and least in those containing a large proportion of white clover. There is considerable question as to the economy of applying fertilizer nitrogen to pastures of this latter type.

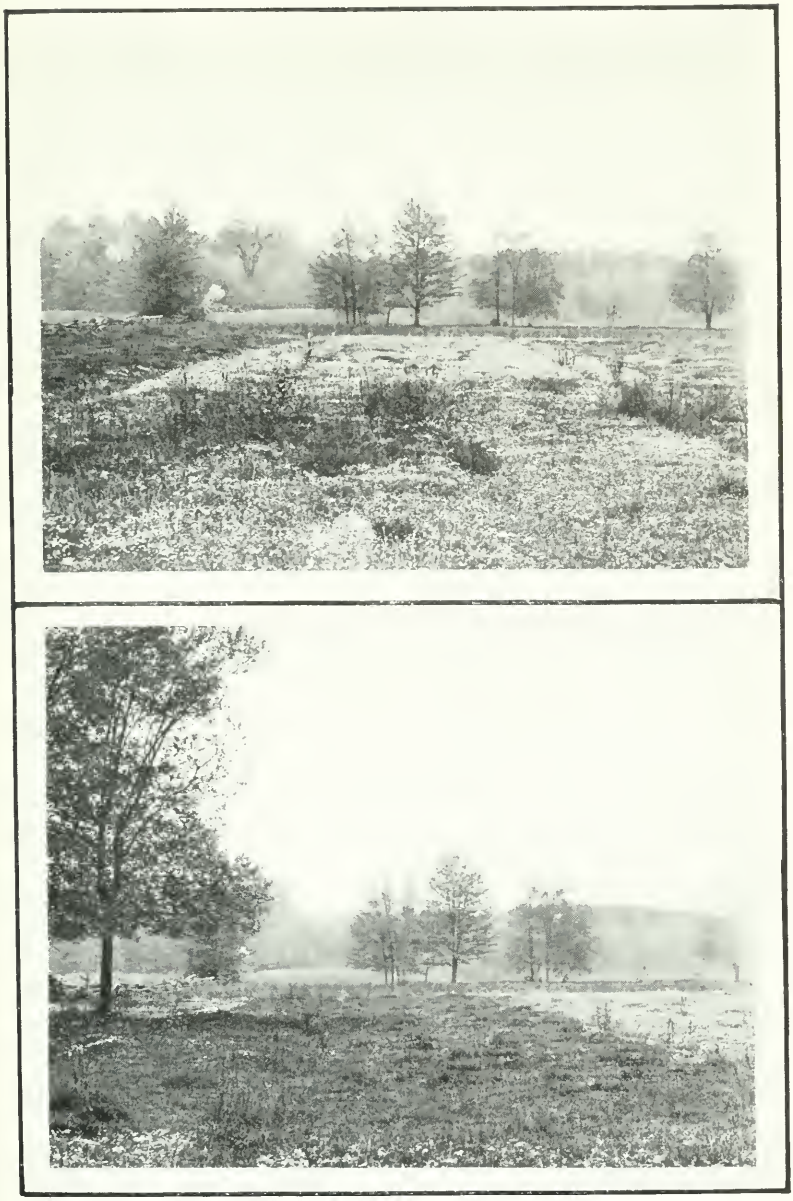

Fig. 2.— Upper) Unfertilized plot and (lower) fertilized plot (basic slag and low-grade sulfate of potash) of Dickinson pasture. Note presence of bluets (white flowers) in unfertilized plot and almost complete absence of them in fertilized plot.

EXPERIMENTS CONDUCTED BY THE MASSACHUSETTS EXPERIMENT STATION

Early Experiments

As previously stated, the first formal experiment in top-dressing permanent pastures established by the Massachusetts Experiment Station was started on the Dickinson Pasture in 1909. The soil is a fine sandy loam of alluvial formation, level and quite free of stones. At the time the experiment was started the pasture was in a low state of fertility as judged by the amount and character of the growth, which consisted of poor pasture grasses and a thick growth of bluets (*Houstonia caerulea* L.). Bluets are among the first weeds to appear in pastures low in lime and other nutrients.

In this experiment there were four plots of 1/8 acre each, two of which, plots 2 and 4, were unfertilized. Plots 1 and 3 received 500 pounds basic slag (14.5-17.1% P_2O_5) and 300 pounds low-grade sulfate of potash (24.8-28.4% K_2O) to the acre in each of the years 1909, '10, '11 and '12. The same treatment was given plot 1 but not plot 3 in 1913, '14 and '15. The principal experiment was discontinued in 1916 due to difficulty in obtaining potash. No quantitative measurements were made of the results of this experiment, but a very good account of the qualitative results is given in notes taken. In the latter part of the season of 1910 it was noted that white clover was coming in on the fertilized plots and the bluets were disappearing. There was no white clover on the unfertilized plots. In May, 1911, it was noted that the bluets had practically all disappeared from the fertilized plots and the growth was nearly all white clover. Notes for the years 1912-15 read very much like those of 1911. A photograph of the fertilized and unfertilized plots (1 and 2) shows the effect of fertilizers in eliminating bluets. (Fig. 2).

In 1915 two new series of fertilizer plots were laid out on the Dickinson pasture, one to determine the effect of different forms of lime when used with potash; the other to determine the effect of varying amounts of basic slag and muriate of potash. Owing to difficulties encountered in securing fertilizer materials during the World War period these experiments were not continued. However, notes made the latter part of the summer show that some change was made in the character of the growth the same season the fertilizers were applied. The greatest improvement was coincident with the heaviest applications of slag and potash.

Experiments in the Period 1921-30

The first of these experiments was started by Sidney B. Haskell[2] in the spring of 1921, and was followed by several others in the period 1921-30. Three of these experiments are reported in this bulletin.

Experiments A and B were situated on property belonging to the Experiment Station and known as the Tillson Farm; experiment C on quite similar soil and topography on a near-by farm. The soil of experiments A and B is a glacial till classified by the U. S. Bureau of Chemistry and Soils as belonging to the Cheshire series. This series is very similar to the Gloucester series so extensive and important as pasture soils in Worcester and other counties of the State, and differs

[2] Formerly director of the Massachusetts Experiment Station. A. V. Osmun of the Botany Department was associated with Director Haskell in the early years of the experiment. A. B. Beaumont took charge of the project in 1928. E. F. Gaskill has supervised the field work throughout the period.

from it primarily in that the Cheshire contains an appreciable amount of sedimentary rock material together with the crystalline material as found in the Gloucester. The topography of both series of soils is rolling to rough, and stones are usually so abundant in both as practically to limit their use to pasture and timber.

TABLE 1.—MECHANICAL ANALYSIS OF SOIL OF EXPERIMENT A
(Sample from untreated area around plots.)

	Per cent
Fine gravel (2.0-1.0 mm.)	0.8
Coarse sand (1.0-0.5 mm.)	5.5
Medium sand (0.5-0.25 mm.)	5.2
Fine sand (0.25-0.10 mm.)	4.6
Very fine sand (0.10-0.05 mm.)	42.2
Silt (0.05-0.005 mm.)	37.2
Clay (0.005 mm. or less)	4.5

The fine-earth portion of the Tillson Pasture soils is a fine sandy loam, as shown by the mechanical analysis of a sample from experiment A given in table 1. The chemical properties of the same soil are given in table 2. These data may be considered as applying to the soil of experiment B which lay contiguous to A, and for practical purposes may be applied to experiment C, except that the latter soil was more acid, having a pH of 5.0. The soil of C was apparently more depleted of plant nutrients than was that of A and B, as indicated by the scarcity of grasses and clovers and the abundance of weeds. Figures 1, 8, and 9 give an idea of the appearance of the land on which experiments A, B, and C were located. Most of the large stones have been picked off by earlier generations of farmers. There was evidence that the field (experiment B) had been cultivated in rows, but on the basis of the testimony of the stumps present when the experiment was started, the last cultivation must have been prior to the crop of timber represented by these stumps. At least two crops of timber have been taken from the land. The area of experiment C has been plowed within the memory of the present owner, but he stated that on account of the abundance of stones on and near the surface he hoped never to have to plow it again. This area has been pastured for many years, and no doubt that alone accounts to a considerable degree for the lower state of fertility of the area as compared with that of experiments A and B, which has been allowed to revert to timber within recent years.

TABLE 2.—CHEMICAL PROPERTIES OF SOILS OF EXPERIMENT A
(Samples taken in the fall of 1928)

	Total P_2O_5	Total K_2O	Total N	Total CaO	Organic and volatile matter	Lime requirement Jones method	pH
	%	%	%	%	%	Lbs. CaO	
Untreated area around plots	0.35	1.15	0.10	0.48	5.41	8474	5.5
Plot 3 unlimed	0.33	1.02	0.11	0.44	5.38	7582	5.2
Plot 3 limed	0.38	1.15	0.12	0.64	6.30	8028	5.5
Plot 4 limed	0.28	1.15	0.11	0.37	5.27	4906	5.7
Plot 5 limed	0.33	1.33	0.12	0.50	5.39	3122	5.6

Note—Analytical work except pH by H. R. DeRose, Fertilizer Control Laboratory.

The mean annual precipitation at Amherst, Massachusetts, where these experiments were conducted was 43.49 inches for the period 1889-1928. For the same period the mean total precipitation for May, June, July, August, and September was 19.53 inches, and this amount was rather evenly divided through the growing season. Thus, under average conditions, there is a favorable rainfall during the pasture season in this region. Occasional droughts of three or more weeks' duration have an adverse effect on the production of the pastures located on the lighter, well-drained soil types.

Experiment A.—The area occupied by this, the first experiment laid out on the Tillson Farm, was on a slight elevation and therefore subject to more leaching than most of the area occupied by experiment B. The flora at the time the experiment was started consisted largely of running cinquefoil (*Potentilla canadensis* L.) together with smaller amounts of grasses, mosses, and weeds. The area was frequently referred to as the "cinquefoil area." There were five plots in this experiment, four of which received different fertilizer treatments as top-dressing, as shown in table 3. One plot received no fertilizer. The plots were 1 rod by 2 rods, and the east half of each plot received limestone in 1921. In 1927, on the basis of experience accumulated since 1921, muriate of potash was applied to all plots except the check, and lime to the west half of all plots except the check, in an attempt to improve the fertility of those plots.

In the first period of this experiment, 1921-26, no quantitative measurements were made of the effects of the fertilizers on yield or character of the flora. However, photographs of certain plots were taken in successive years of 1921, '22, and '23, which speak eloquently of the changes in the character of the vegetation. By referring to figures 3-5 it may be seen that a vegetation consisting largely of cinquefoil was in the course of three years transformed by chemicals to a vegetation composed largely of white clover and grasses. No seed was sown on these plots. It should be noted, however, that 1923 was a good "white-clover year" in this section.

On account of the larger economic importance which nitrogen fertilizers were assuming, the nitrogen plots were given a double application of this element in the form of Chilean nitrate of soda in 1928. The results of this treatment and the cumulative effect of the previous treatments are shown by figures on yield of two cuttings of grass, as given in table 4. The rainfall was heavy in 1928 and grass and clover grew exceptionally well. The area was mowed in 1928 but had been pastured in previous years, and it is held that the figures fairly represent the productivity of the respective plots induced under actual pasture conditions.

While the lack of uniform treatment of the plots through the period 1921-28 precludes certain desirable comparisons, some interpretations of value may be made. First, there is the evident response to an application of lime made seven years previous (Plot 3 E vs Plot 3 W). Second, the east half of all plots was definitely superior to the west half, although the west half of all except plot 3 received lime in 1927, while the east half received it in 1921 only. The application of 1927 doubtless had some, even if only a slight effect in 1928. It then becomes evident that more than a year may be required for limestone to exert its full effect. The data of table 4 also strikingly show the cumulative effect of potassium and phosphorus. Unfortunately, no deductions can be drawn as to the relative effectiveness of these two elements. Finally, the effect of nitrogen is shown to be marked. In combination with lime, phosphorus, and potassium it has proved very effective. The effect of these treatments on the protein content of the grass

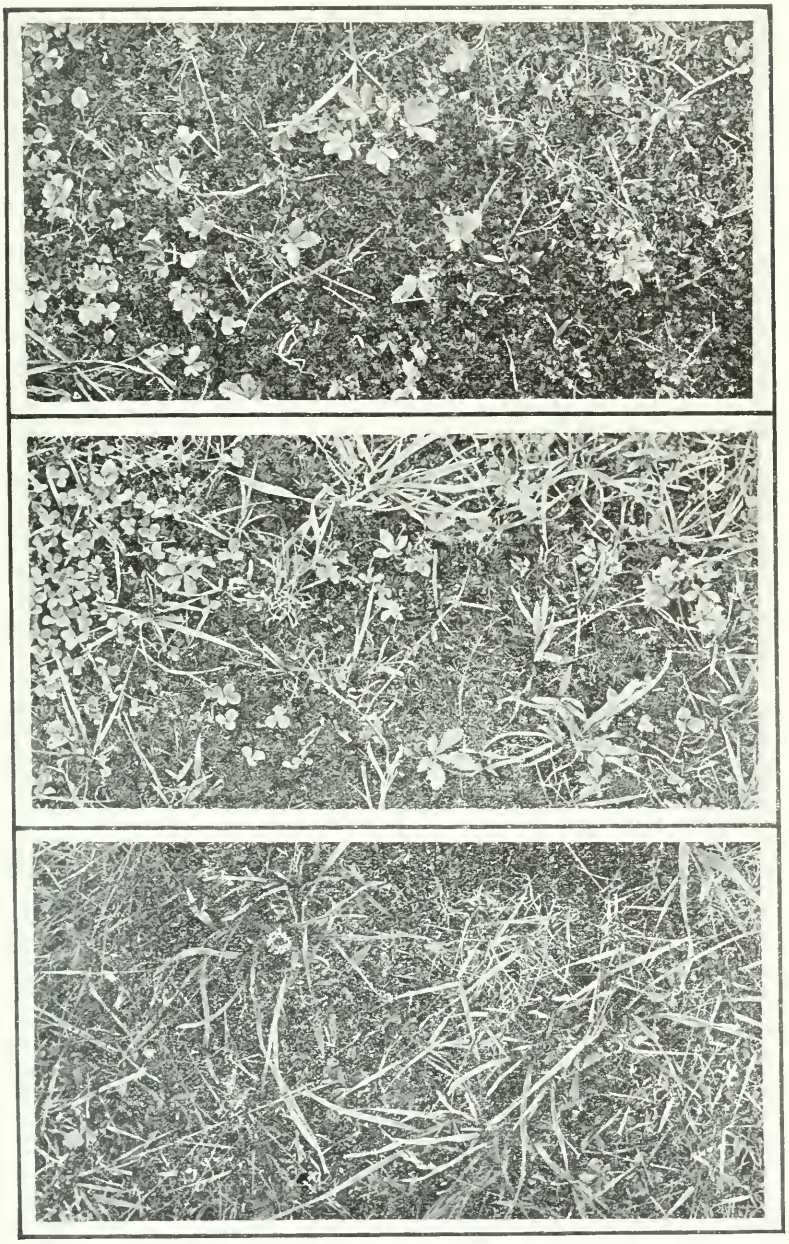

Fig. 3.—Lime alone brought in grasses and clover. (Exp. A, Plot 3—L.)
Upper—1921, before the application of lime.
Middle—1922, one year after application.
Lower—1923, two years after application.

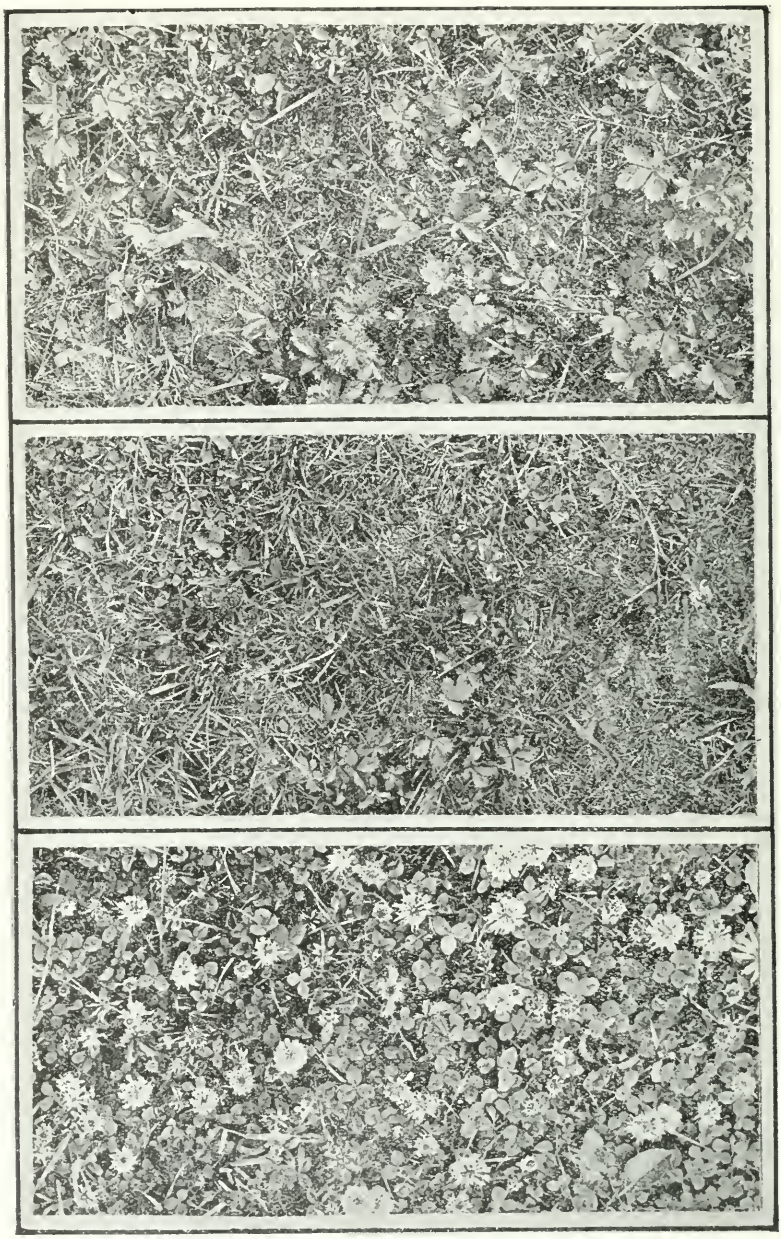

Fig. 4.—Lime, phosphorus and potash were more effective than lime alone in changing the character of the vegetation. (Exp. A, Plot 5—L, P, K.)
Upper—1921, before the application of fertilizer.
Middle—1922, one year after application.
Lower—1923, two years after application.

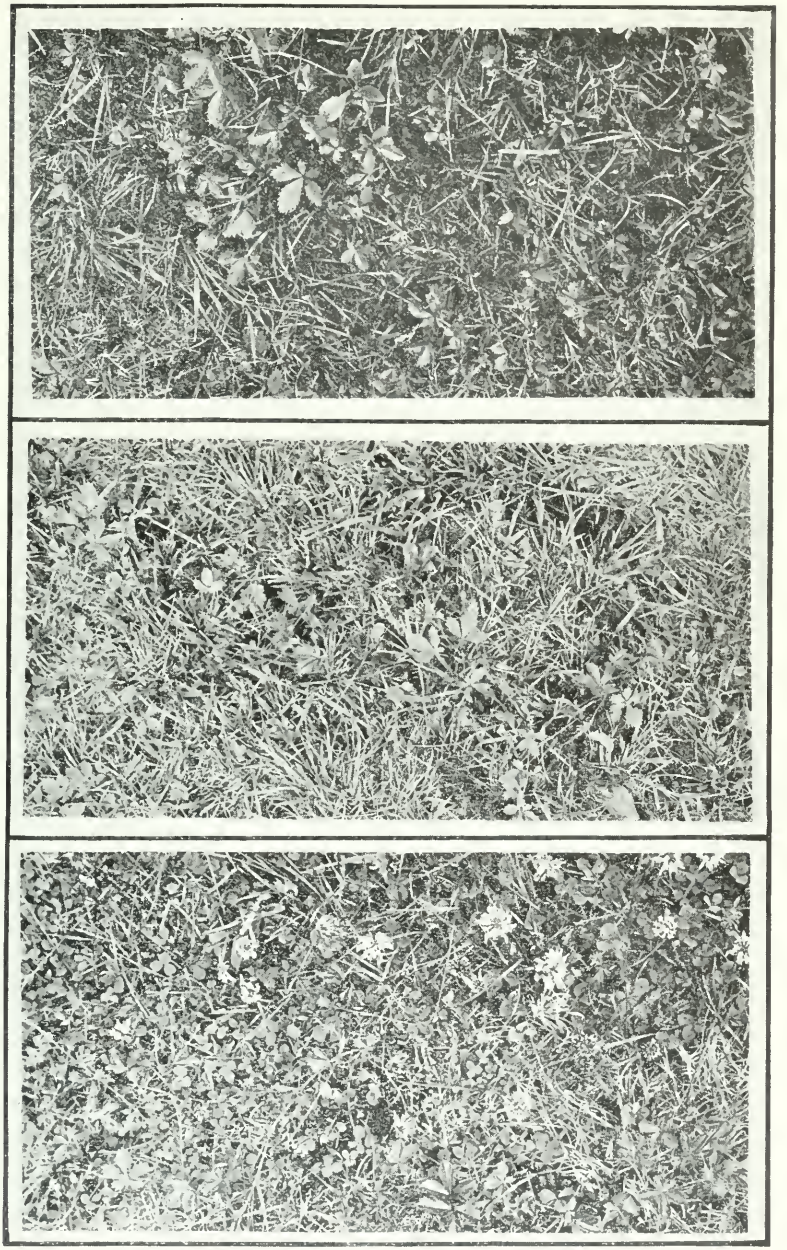

Fig. 5.—The addition of nitrogen to a complete mineral treatment increased the yield but did not improve the character of the vegetation. (Exp. A, Plot 4—L, P, K, N.)
Upper—1921, before the application of fertilizer.
Middle—1922, one year after application.
Lower—1923, two years after application.

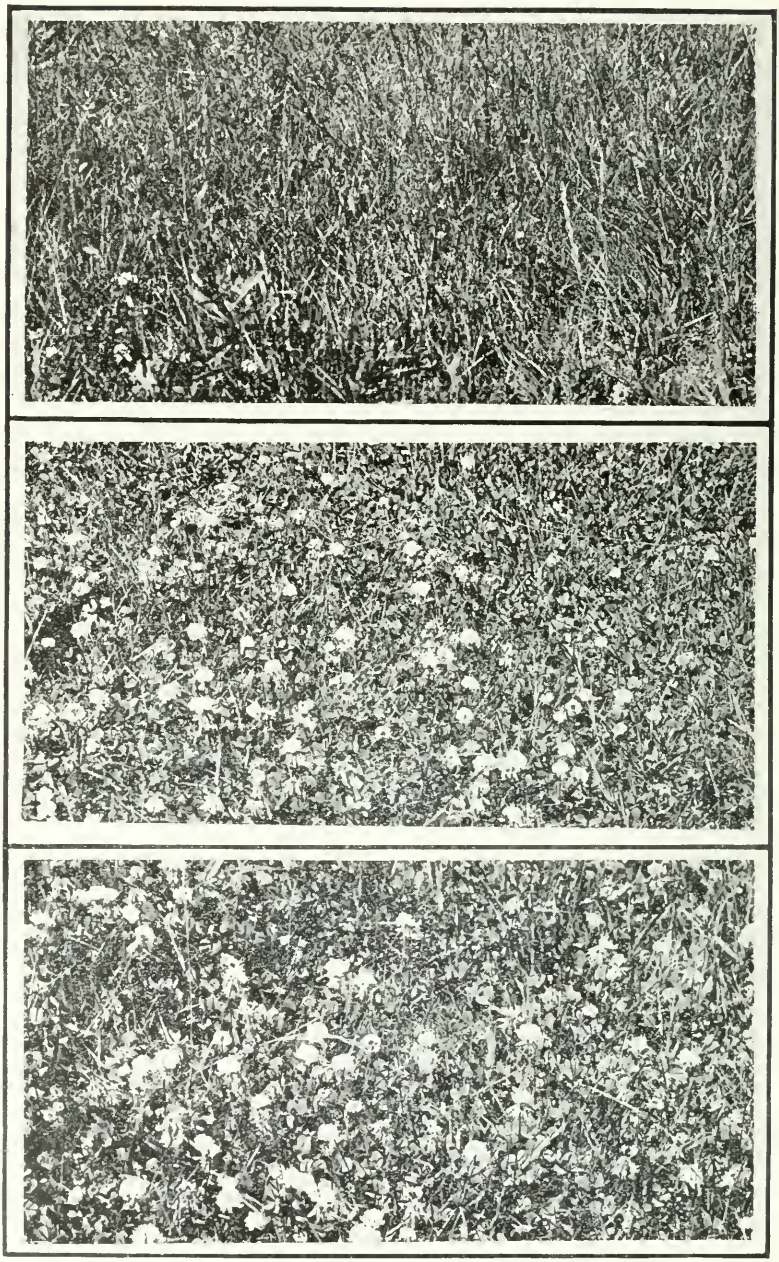

Fig. 6.—Upper—Phosphorus alone (Plot 4—2P) did not cause much clover to appear.
Middle—Potassium alone (Plot 5—2K) was more effective.
Lower—Phosphorus and potassium (Plot 9—2P, 2K) was most effective.
(Exp.B, series I, unlimed, 1923.)

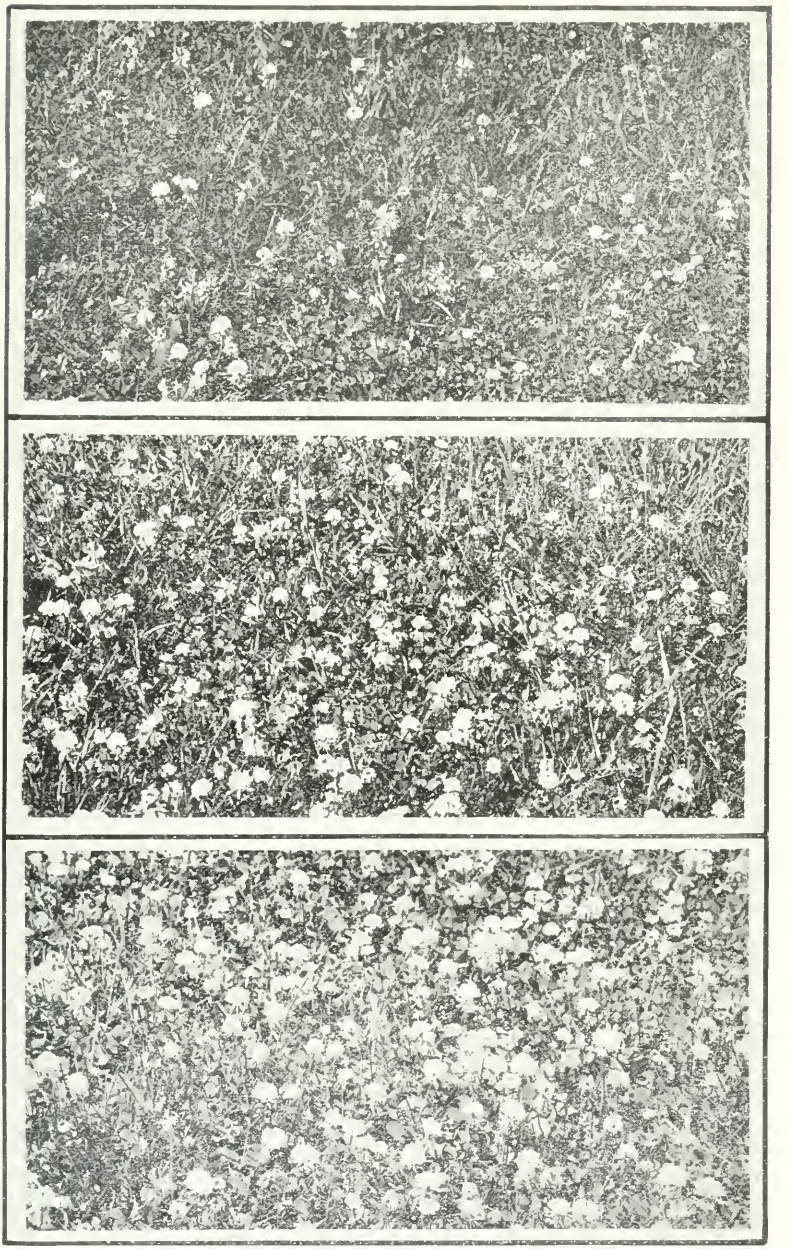

Fig. 7.—Lime increased the effectiveness of phosphorus and potassium. (Same treatments as Fig. 6, but limed, 1923.)

is brought out by the figures of table 5. The highest percentage of protein was in plot 5E which received lime, potassium, and phosphorus. This plot also had the most white clover. But, largely on account of the greater yield, plot 4E, which received lime, potassium, phosphorus, and nitrogen, furnished the most pounds of protein per acre.

Experiment B.—This experiment was laid out in the fall of 1921 and the spring of 1922. As shown in table 6, each original treatment was replicated three times (six times not considering spring and fall applications), and to that extent the experiment was better planned than was experiment A. After the first application of fertilizer, all subsequent applications were made in the spring.

During the first year of this experiment only slight effects chargeable to fertilizers were observed. In the spring of 1923, a white-clover year, the effects of the fertilizers were marked. After two or three weeks of grazing the cattle were excluded from the field by means of a temporary fence. The effects of the fertilizer were measured first by giving each plot a rank according to the proportion of white clover and grass present, the best being ranked at 100 and the poorest at 0. There were five independent sets of observations by different persons. Means of these estimates are given in table 7. According to this evidence, there was a striking response first to lime, second to potassium, and third to the combination of lime, potassium and phosphorus. Nitrogen added nothing to the appearance of the plots which received this element in addition to minerals. Later in the same season square-yard areas were harvested from certain plots, dried, weighed and analyzed. The fence was then opened and the cattle given access to the pasture. The data are given in table 8. Unfortunately, yields were not taken from the plots which received nitrogen, and consequently no quantitative comparison between minerals alone and minerals plus nitrogen can be made for the first period of this experiment. Part of the data of table 8 were reported in 1926 (7), but for the sake of completeness these as well as additional data are given here. The high percentage of protein which resulted from the use of potash and lime was no doubt due to the effect of potassium on the proportion of clover. However, potassium in combination with phosphorus and lime was more effective than any other combination or single treatment.

Experiment B was continued under pasture conditions with fertilizer treatments as shown in table 6 until 1929, when an attempt was made to secure additional quantitative data. It happened that the summer of 1929 was extremely dry, with a total rainfall of 2.24 inches for July and August against a normal of 8.57. Yield data were obtained, but since they were doubtless seriously affected by the abnormal weather conditions, they are not reported here. However, since the character of the vegetation was fairly well determined before the effects of the drought became serious, it is thought that the data on botanical composition fairly show the effects of fertilizer treatment up to and including the spring of 1929. These data are summarized in table 9. They show, first, the advantage of lime in combination with other materials, except for the nitrogen combination, in inducing white clover to come in; second, the superiority of treatments containing potassium for encouraging clover; third, the effect of gypsum, both alone and with lime, in the encouragement of clover; and finally, a pronounced positive effect of nitrogen on the presence of white clover.

In table 10 are given data on yields obtained from plots of Experiment B in 1930. Clippings were taken from 3 areas of 3 square feet each in each plot of 1 square rod. A grouping of the figures according to series having a total of 4, 5,

or 6 applications of fertilizer in the 10-year period shows that the series which received 5 applications slightly outyielded those which received 4 and 6, 4 being the lowest of the three. It is believed that these differences are too small to be of any significance. It appears that under the conditions which prevailed during this experiment, drought and all considered, 4 applications of fertilizer furnished an abundance of nutrients—that is to say, a sufficient quantity of minerals apparently had been added. Nitrogen was a serious limiting factor in this experiment, and that, if supplied in a soluble form, should be added annually.

In table 11 is given a summary of the yield data arranged according to fertilizer treatment, with and without lime. An examination of these figures shows that marked benefits resulted only from lime and from the nitrogen-phosphorus-potassium combination. By comparing table 11 with table 8 it may be seen that the marked response to minerals obtained in 1923 did not manifest itself in 1930. The reason for this difference apparently lies in the proportion of white clover in the vegetation of the two years. As Haskell (7) has pointed out, white clover "comes and goes." Irrespective of the soil treatment, there is a pronounced variation in the proportion of white clover from year to year. In so-called clover years white clover appears abundantly on soils supplied with plant nutrients and moisture, in off years it disappears from those same areas due to causes which are not understood.

1923 was a white-clover year, 1930 was not. In support of this point, note the difference in the percentage of white clover in the plots of series I in 1929 and 1930, as given in table 12. This series had the highest percentage of clover of all series in both years. Why the marked change in flora in the period of one year? Was the drought of 1929 an important factor? The causes of such changes are not known, but the changes do occur and should be taken into consideration in the interpretation of pasture data. Thus, it seems reasonable to conclude that the lack of response to minerals in 1930 was due to the fact that white clover was almost entirely absent from the plots in that year. On the other hand, the response to nitrogen was marked because of the grasses.

In table 13 is given the percentage of protein, phosphoric acid and calcium oxide in the 1930 clippings. The figures show in a general way the agreement between character of fertilizer applied and composition of the crop. Vegetation from plots which received nitrogen, phosphorus, and lime was richer in those elements than that from plots which did not receive the same elements in fertilizers. The difference in respect to nitrogen (expressed as protein) is more marked in 1930 than in other years due, no doubt, to the practical absence of clover in 1930.

It is believed that the higher content of nutrients in vegetation from the limed and fertilized plots accounts for the greater palatability of the vegetation as noted in the field. This applies particularly to lime and nitrogen. It was repeatedly observed that the plots which received these nutrients were more closely grazed than those which did not. This can be seen by a close inspection of figure 8.

Experiment C.—This experiment was laid out in 1924 by M. O. Lanphear[3] in order to obtain certain field data to be used in an ecological study of pasture cover. The area occupied by this experiment was particularly attractive for the purpose on account of the poor quality of herbage. This, as shown by figure 9

[3] Formerly instructor in Dept. of Agronomy. Work reported here was part of thesis submitted for M. S. degree.

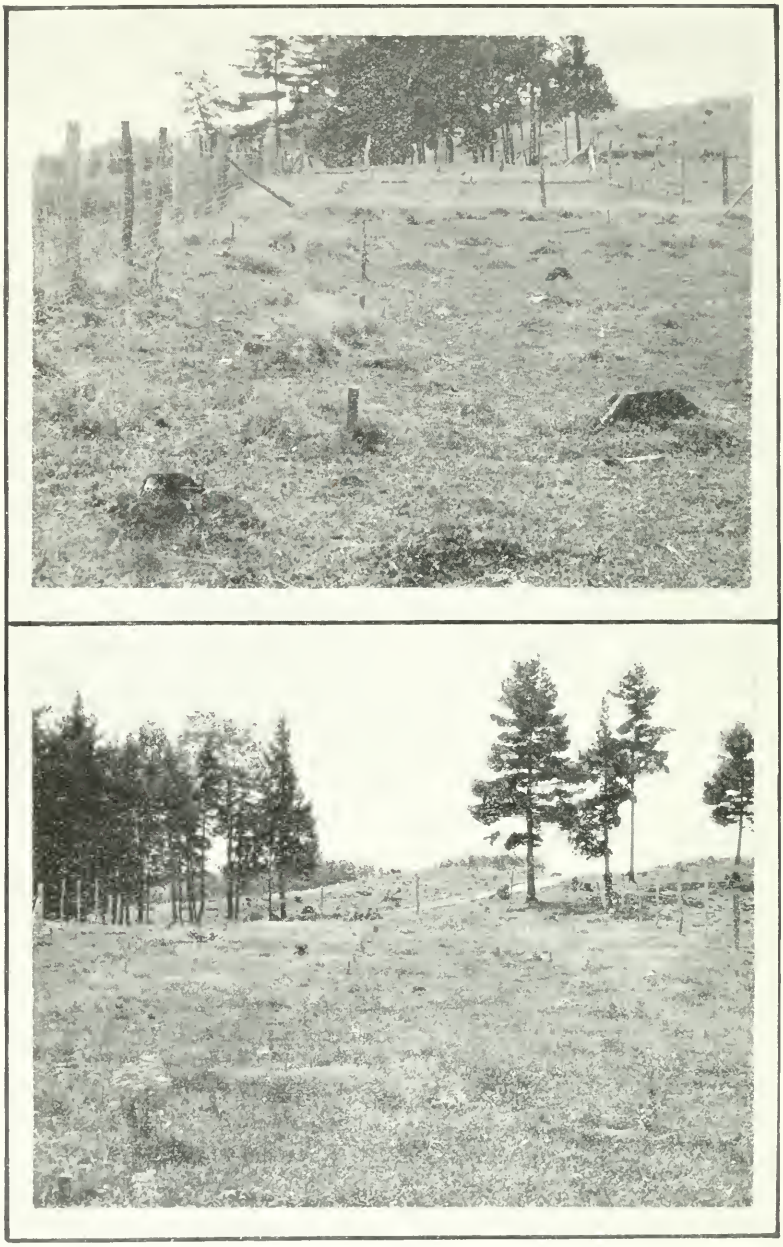

Fig. 8. Upper—Uneaten grass on unfertilized strip between fence and stakes, and closely grazed limed plots to right of stakes. (Exp. B.)
Lower—The animals allowed more grass to go to seed on unlimed plots to left of stakes than on limed plots to right of row of stakes. (Exp. B.)

consisted almost entirely of haircap moss (*Polytrichum commune* L.), with occasional plants of running cinquefoil, sorrel and bent grasses. The pasture was poorer than is ordinarily considered worth spending any money on for improvement; yet in years past it was no doubt a good pasture. Being located conveniently near the barn, it stood to repay an investment for improvement better than a like field farther removed. The original experiment was laid out in duplicate series, the plots of each series receiving treatments as shown in table 14. Other plots were added to one of the series (east) in 1929 when the original fertilizer treatments were repeated, but the additional plots are not considered in this report. Plots 1-20 of the west series were plowed in 1926, but plots 21-30 of the same series are still clearly defined by effects on the vegetation of fertilizer applied in 1924. (Fig. 11). Plots 23-30 of both series received an application of a mixture of Kentucky blue grass and white clover seed in June 1924. The seed was not worked into the soil in any manner, merely scattered over the surface.

Most of the growing season of 1924 was rather dry. During that first year of the experiment there was little or no visible effect either of the fertilizer or the seed. In 1925, a good year for pastures, the effects of both fertilizer and seed became evident to the eye. According to Lanphear[4], white clover was dominant on those plots which received a complete mineral treatment, consisting of lime, superphosphate, and muriate of potash, and the seed mixture in addition. Plots which received the complete mineral treatment but no seed, contained no white clover. In these plots redtop predominated. Kentucky blue grass was not present in appreciable proportion. Certain combinations of minerals, together with the seeding, caused appreciable growth of white clover, but no other combination was as effective as the complete treatment. (Fig. 10).

In the spring of 1926 some of the plots of the east series of this experiment were fenced off from the cattle for a few weeks. Figure 11 gives a good idea of the effect of fertilizer and seed on the character of the growth. As a result of this phase of his experiment, Lanphear suggested the possibility of seeding small amounts of white clover on pastures as a practicable method of determining whether the chemical factors were favorable for this crop.

In 1929 the east series of plots in experiment C was again fertilized as in 1924, and the east half of each plot received in addition Chilean nitrate of soda at the rate of 193.6 pounds (30 lbs. N) per acre. The area was fenced off from the grazing cattle, and in July the grass from each plot was harvested, dried, weighed, and separated into grasses, clovers, and weeds. The fence was opened soon after the harvest of the crop and the cattle allowed to graze the plots for the rest of the season. This procedure was repeated in 1930, except that two clippings of grass were made instead of one. Data from this experiment for the two years, including yield of dry matter, yield of protein, botanical composition and ratios of dry matter and protein are given in tables 15-19. First, any treatment, small or large, single or combined, was beneficial. Generally, the benefit increased with the amount of fertilizer added. A combination of two materials generally produced more than a single fertilizer, and a combination of three or more elements more than two, except that the combination of any element with nitrogen yielded more than any three without nitrogen. Nitrogen alone was not as effective as other elements alone, but nitrogen in combination with other elements was more effective than any other element. These relationships are brought out by the figures in table 17 in which results have been calculated in

[4] Lanphear, M. O. An ecological study of pasture cover. Unpublished thesis. Mass. State College Library.

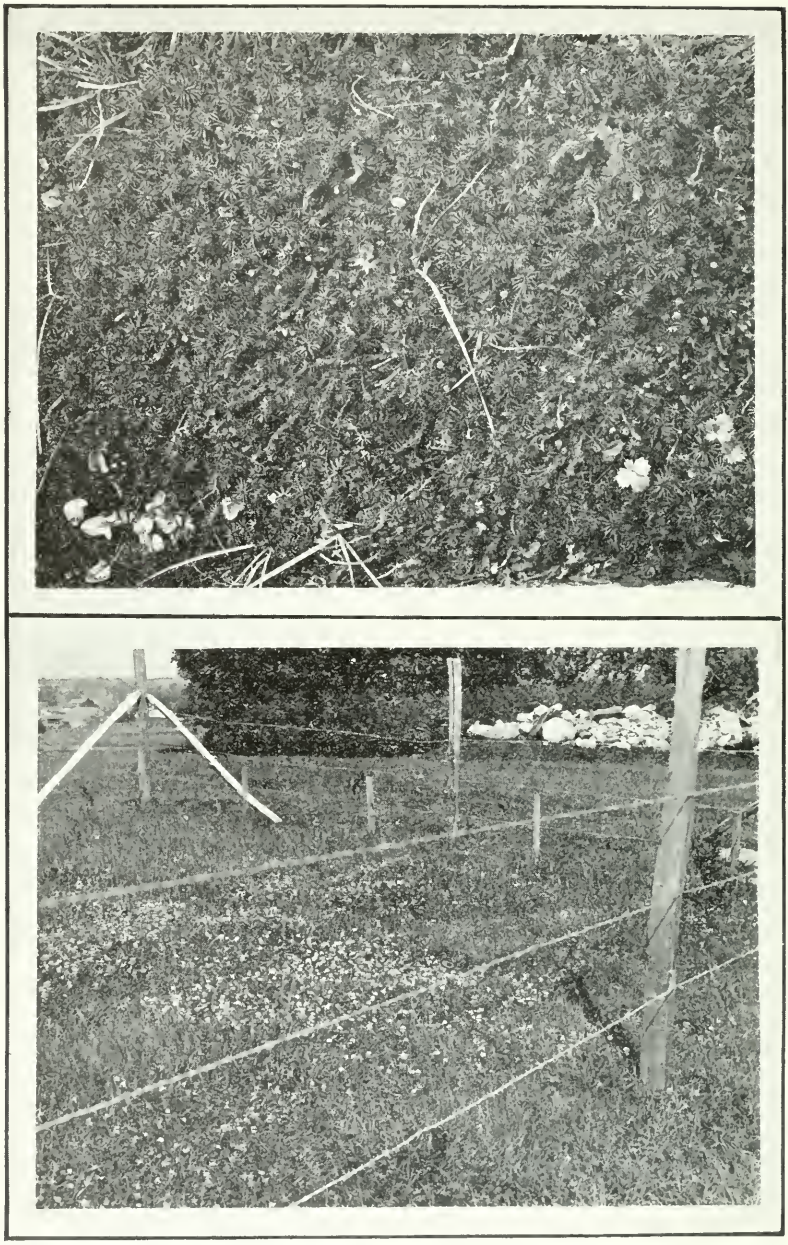

Fig. 9.—Upper—Typical vegetation (mostly haircap moss) before treatment. (Exp. C.) Lower—Note abundance of white clover on area inside the fence, in left foreground. (Exp. C, Plot 22—3L, 3P, 3K, 1929.)

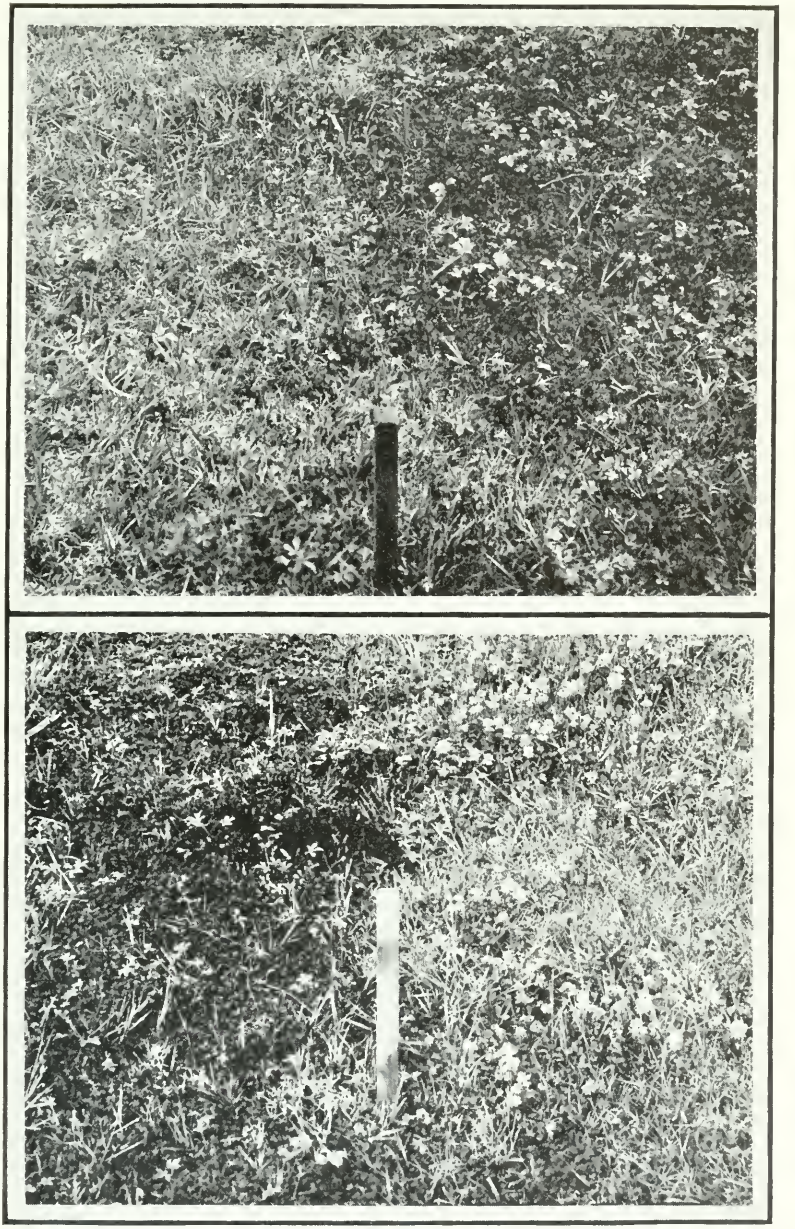

Fig. 10.—Seeding hastened the appearance of white clover where necessary fertilizer was supplied. (Exp. C, west series, 1926.)

	Upper—Not seeded	Lower—Seeded
Left of stake	Plot 14—2L, 2P, 2K	Plot 30—Check
Right of stake	Plot 15—Check	Plot 29—2L, 2P, 2K

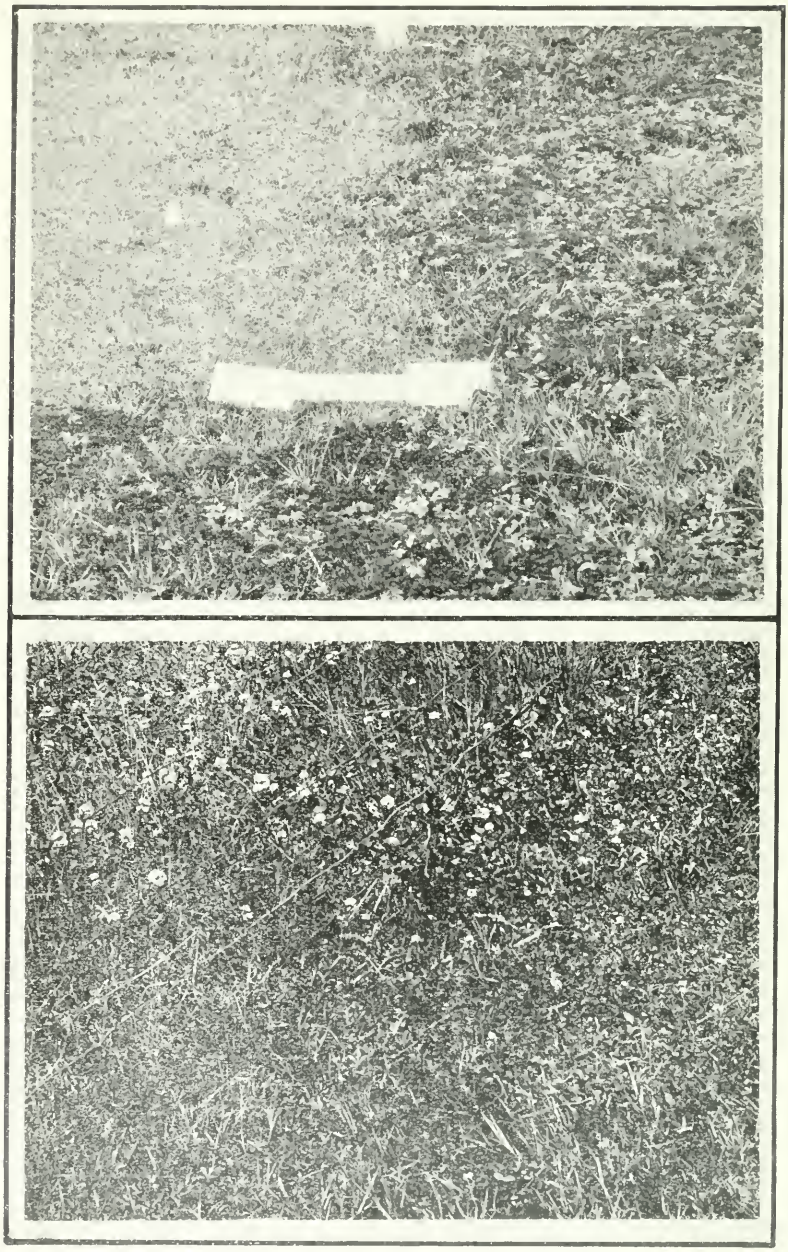

Fig. 11.—Persistence of the effect of treatments is shown by these photographs.
Upper—In fall of 1928, 4½ years after fertilizing—Plot 29 (2L, 2P, 2K) in upper left-hand corner, rest unfertilized.
Lower—In spring of 1929, 5 years after fertilizing—Plot 7 (L, P, K.) Note presence of considerable clover.

terms of grass and clover. However, it should be remembered that nitrogen has been used in this experiment for only two years, the minerals seven years.

The question of the effect of applied nitrogen on the presence of white clover in pasture vegetation is one of considerable interest and importance. Although the results of only two years are inadequate for the drawing of final conclusions on this question, they are worth considering as showing trends. Figures of table 15 show that in 1929 there were 15 cases in which the percentage of clover was more with the addition of nitrogen, 13 in which it was less, and 2 in which it was the same. At the time of the first clipping in 1930, the cases were 14 in which there was more clover with the nitrogen, 7 in which it was less, and 9 in which it was the same (or no clover). At the time of the second 1930 clipping there were 8 cases in which the clover was more, 15 in which it was less, and 7 in which it was the same (or none) with the added nitrogen. Thus this experiment affords only meager evidence of a trend toward reduction in stand of white clover due to the application of nitrogen, and no conclusion can be drawn. The evidence at hand indicates, however, that white clover will maintain itself better in the presence of applied nitrogen if there is also a generous supply of calcium, phosphorus, and potassium.

The dual effect of nitrogen and potassium on the nitrogen content of the herbage is well brought out by the data of table 19. In plots where the percentage of clover was low and grass high, the added fertilizer nitrogen almost invariably caused an increase of nitrogen (figured as protein in table 19) in the crop. On the other hand, potassium in connection with lime caused an increase in the percentage of white clover, and where this plant was abundant, the percentage of protein ran high—sometimes much higher on the portion of the plot with minerals only than on that portion which received minerals and nitrogen. Thus the percentage of protein in the crop was a resultant of these two, and probably other factors. The interaction of the two factors caused some interesting results. For example, in plot 1 there was practically no clover, and the percentage of nitrogen in the grass and weeds was almost doubled by the application of nitrogen; while on plot 7 the relationship in respect to nitrogen content was practically reversed because of the presence of more clover in the portion of the plot which received only minerals. On plot 22 the clover was abundant in both portions of the plot and consequently there was a high protein content in the vegetation from both sides, it being a little higher where nitrogen was applied. Table 19 further shows, however, that although the percentage of protein was sometimes higher in the crop which did not receive nitrogen than in that which did, the total pounds of protein per acre were invariably higher where nitrogen was used because more pounds of dry matter were produced. These examples indicate the importance of data on botanical composition in the interpretation of pasture experiments of this type.

That the full effect of nitrogen is not always shown by the figures on yield of dry matter is further shown by the ratio comparisons in tables 18 and 19. With few exceptions, all of which were due to the greater percentage of clover in the no-nitrogen portion, added nitrogen caused a higher ratio of protein than of dry matter in the plots receiving minerals only and minerals plus nitrogen respectively.

From experiment C was first obtained evidence (3) of the toxicity of sodium nitrate for a species of moss (*Polytrichum commune* L). This moss is common on Massachusetts upland pastures which have become depleted in plant nutrients.

The toxic effect was first observed in 1929 soon after the nitrate was applied. At first the effect was thought to be a temporary foliage burn caused by contact with the salt, but later it was found to be permanent.

The disappearance of the moss is not due to crowding by grasses and clovers as happens with some plants and treatments. The moss is actually killed. The toxic effect increases with an increase in the amount of nitrate applied. The effect is somewhat cumulative from year to year, so that small applications made annually may in time produce the same effect as large ones, it seems. Since the first observation of the toxicity of sodium nitrate for this moss was made on experiment C, the effect has been observed at several other places, and experiments have been started for studying the problem further.

Discussion of Results

All experiments reviewed in this bulletin have shown that chemical fertilizers were generally beneficial on depleted pastures. There have been definite and measurable beneficial changes in the character of the vegetation. In all cases where records of yields were secured these were generally increased by the fertilizers.

In the Dickinson pasture experiment a rather generous annual application of basic slag and low-grade sulfate of potash practically displaced bluets with white clover. No nitrogen was used in this experiment. The soil on which the experiment was located is not typical of any large proportion of permanent pastures in Massachusetts.

Experiments A, B, and C were located on soils which are typical of a large proportion of permanent pastures in the state—on soils notably deficient in plant nutrients. These experiments, likewise, have shown beneficial changes in vegetation from the application of lime, phosphorus, and potassium. Of all single materials used in these experiments, lime was most effective in producing desirable changes in the character of the vegetation. Lime and potash were the most effective combination of two elements in producing such changes; but lime, potash, and phosphate were the most effective of all. Since gypsum alone induced a fair percentage of white clover in the stand on experiment B, there is some evidence that it was the calcium in the lime which produced the principal benefit rather than the effect of lime on the soil reaction.

With the exception of the elimination of haircap moss, nitrogen applied as nitrate of soda has not produced any profound changes in the character of the vegetation, such as were caused by the minerals. On the other hand, nitrogen added seems not to have interfered with the action of the minerals in encouraging white clover. Experiment B has given definite results on this point. Data from experiment C are inadequate for a conclusion.

While nitrogen has not been an important positive factor in improving the quality of the pasture flora, its effect on the quantity has been marked. It has produced the greatest relative increase in yield when used alone, but the greatest absolute increase when used in connection with minerals. In table 17 figures are given which show average increases in grass and clover due to added nitrogen in experiment C of 48 to 211 per cent with minerals, and 311 per cent without minerals. Other data from the same experiment show that in individual cases added nitrogen caused yields several times those from minerals alone.

The observations and records of experiment B have brought out the importance of white-clover years in the measuring and interpretation of results. Due to causes not fully understood, white clover comes and goes by seasons. In

some years it is especially abundant in soils having a sufficient supply of nutrients and scarce or entirely absent from those low in nutrients. In off years white clover may be and usually is in small proportion on plots low in nutrients. It follows that if results of treatments are measured in off years they will be quite different from those obtained in clover years. An example of this is afforded by a comparison of the results of experiment B in 1923 and 1930. In 1923, a clover year, there was a marked response to phosphorus and potassium, as shown both by percentage of clover and yields. In 1930, an off year for white clover, there was very little response to phosphorus and potassium, but a marked response to nitrogen. The vegetation was nearly devoid of clover that year. In the same field in 1929 there was considerable white clover. The comparison is brought out by the figures of table 12.

The dual effect of applied nitrogen and potassium on the protein content of the herbage has been well brought out by the data from experiment C. Potassium generally encourages the growth of white clover, and nitrogen appears to discourage it under some conditions and at the same time increases the percentage of protein in the grasses and weeds. The interaction of these factors has produced some interesting results. In some cases they have worked against each other and in others they have worked in the same direction causing, thereby, a rather high protein content, as was shown in the clippings from plot 22.

Not only the applied nitrogen, but also the calcium and phosphorus have been reflected in the composition of the plants. It is thought from observations made on experiments B and C that both the nitrogen and calcium-containing fertilizers were important factors in determining the palatability of the herbage.

Experiment C has brought out the value of seeding white clover on areas practically devoid of it. In many cases white clover appears spontaneously after fertilizers have been applied, while on some areas there is apparently not sufficient seed present, and best results are obtained only after the pasture is seeded. The seeding operation may be beneficial through hastening the process.

PRACTICAL APPLICATION OF RESULTS

It is difficult if not impracticable to translate these results into terms of profit and loss. Of course, the safest policy is to let each farmer draw his own conclusions and make his application on the basis of his own judgment, being governed by his conditions. Nevertheless, the following deductions may safely be made.

First, there is the question of the type of pasture vegetation with which one may expect sufficient improvement to make the investment pay. Results have shown that with vegetation about as poor as may be found on any New England pasture tremendous improvement can be effected, but at a questionable cost. Everything else being equal, it seems that the money for improvement should be invested first in those pastures which have a fairly good vegetation to begin with.

The question of physical conditions, texture and structure of the soil, and topography, which have much to do with the ability of a soil to withstand drought, should be considered. These conditions are probably of considerable importance in determining white clover cycles, and we have seen that clover years play an important role in the success of mineral treatments.

In the choice of a pasture for improvement the location of the area must be considered. A pasture occupying a more or less advantageous position on account

of its proximity to the barn, to a water supply, to other pastures which are productive, or for any other reason, may well receive more attention than one not so well situated.

The experiments on the Tillson and Hobart Farms together with some unpublished results from Worcester County experiments lead to the conclusion that over a period of years the best results in the top-dressing of Massachusetts upland pastures may be expected from an initial application of lime supplemented with a phosphate, a potash salt, and a nitrogenous fertilizer. It is believed that under our typical soil conditions 1 ton of ground limestone (or three-fourths as much hydrated lime) every 6 years, 480 pounds of 16 per cent superphosphate and 160 pounds of muriate of potash every 3 years, and 160-320 pounds of nitrate of soda (or its equivalent in other available form) annually will be sufficient for most demands. At present (early 1932) prices the initial cost of the mineral application is $14.33 per acre. If the cost be prorated over the number of years between applications, the annual cost becomes $3.69 plus a small interest charge per year. The cost of 160 pounds of nitrate of soda is $3.94. Therefore, the total annual cost as figured is $7.63 per acre. While the best return from nitrogen may be expected when it is used on fair to good sods, the fact that the response to nitrogen generally comes sooner than that to minerals, makes it seem advisable to apply nitrogen from the beginning of the improvement program.

If it were possible to predict early enough in the season whether a given year was to be a "clover year," most or all the nitrogen might be omitted for the sake of economy; and in off years for clover, the nitrogen ration might well be increased 50 or 100 per cent. This procedure appears feasible for those farmers who have enough early pasture and are more in need of mid- and late-summer pasture. Under such circumstances a decision as to the nitrogen application could be deferred until the early part of June. It should be noted, however, that some fertilizers, especially nitrate of soda, are poisonous to cattle, and a rain or several days should intervene between the application of fertilizers and the return of the cattle.

These experiments are not capable of a strict monetary interpretation because of the many variable and uncontrollable factors which have contributed to the results. Indeed, such an interpretation is always open to misconstruction and abuse. Further, there is such a wide variation in individual ability, that what one farmer may turn into success may prove a flat failure for another. However, it is believed that an average annual investment of $5 to $10 in lime and fertilizer for Massachusetts upland pastures will yield a fair return on the investment. After all, the agronomic aspects of the question are fairly clear, and the rest of it is largely a matter of business judgment. Fluctuation in prices of fertilizers and of milk will largely determine the wisdom of the investment.

From our data we have no evidence that smaller amounts of fertilizer than those mentioned cannot be used to advantage, nor that a better distribution may not be possible. It is quite likely that it may be more advantageous to apply lime in smaller amounts but more frequently. Furthermore, from the experiments reported we have no evidence that certain other carriers of nitrogen, phosphoric acid, and potash, different from those used in our experiments, cannot under some circumstances be advantageously substituted for them.

In this connection it should be remembered that not only may more feed and more protein per acre be expected from top-dressing pastures, but also a feed richer in calcium and phosphorus may be expected. Thus, the health of the animals may be safeguarded or improved by the use of mineral fertilizers.

Finally, it should be emphasized that pasture improvement by top-dressing is a long-time investment. Very little improvement from lime, phosphorus, and potassium, may be expected the first year after application. Nitrogenous fertilizers will normally bring returns the first year of the application in accordance with the quality of the vegetation when applied.

SUMMARY AND CONCLUSIONS

The result of four pasture experiments conducted in Massachusetts are summarized as follows:

1. In the first experiment, on an alluvial soil not typical of much of the permanent pasture land of Massachusetts, basic slag and low-grade sulfate of potash changed a pasture flora consisting largely of bluets (*Houstonia caerulea* L.) and poor grasses to one composed largely of white clover and good grasses.
2. The three other experiments were conducted on an upland glacial till soil characteristic of much of the dairying section of Massachusetts. In these experiments pasture flora consisting first, mainly of running cinquefoil (*Potentilla canadensis* L.); second, mainly of haircap moss (*Polytrichum commune* L.); and third, of smaller proportions of these together with some grasses and clovers, were transformed to flora consisting mainly of white clover, bent grasses, and Kentucky blue grass.
3. With the exception of a toxic effect of nitrate of soda for haircap moss, lime was the most effective single material in producing desirable changes in vegetation. Lime and potash were the most effective combination of two materials; but a combination of lime, potash, and phosphate produced the greatest change in vegetation. Nitrogen produced the greatest relative and absolute increases in yield, and was more effective when used with minerals than when used alone.
4. The addition of nitrogen to the mineral treatments did not reduce the percentage of white clover in one experiment, but there was some indication of a trend in that direction in another. In the presence of nitrogen, white clover was maintained better with an abundant supply of minerals than with a poor supply. Potash generally encouraged the presence of white clover and thereby raised the protein content of the herbage.
5. On plots having a vegetation largely of grass, applied nitrogen very generally caused an increase in yield of dry matter which varied from little to several times that with minerals only. Generally, the added nitrogen caused a relatively larger yield of protein than of dry matter. On plots having a large percentage of clover, nitrogen had little or no effect.
6. Plots which received fertilizer were more closely grazed than unfertilized plots. This effect was noticed particularly on plots which received lime in addition to the fertilizer. Chemical analysis of the clippings showed that the addition of calcium (lime), nitrogen, and phosphorus caused an increase of these elements in herbage. From this it appears that the composition of the herbage, as influenced by the fertilizers, is an important factor affecting palatability.
7. Botanical analysis was made of several of the crops of these experiments, and the results brought out the importance of such work in the interpretation of results. Data obtained in white-clover years may lead to quite different conclusions from those drawn from results in off years.

8. Seeding of Kentucky blue grass and white clover seed hastened the appearance of white clover in one experiment, the only one in which it was tried. It appears, however, that the ultimate result will be the same whether or not white clover seed is sown. On some pastures the appearance of white clover may be hastened one or two years by seeding.
9. It is concluded that best results from the top-dressing of upland pastures in Massachusetts may be expected from the use of lime supplemented with a phosphate, a potash salt, and a nitrogenous fertilizer. In the experiments reported, ground limestone, 16 per cent superphosphate, muriate of potash, and Chilean nitrate of soda were used. Since no other fertilizers were used in the experiment, no positive statements can be made regarding them. However, it is believed that under some conditions certain other materials can be substituted for those used.
10. Although the results of these experiments are not capable of a strict monetary interpretation, it is thought that an average investment of $5.00 to $10.00 per acre in lime and fertilizer for Massachusetts upland pastures will yield a fair return on the investment. This price range will at present (early 1932) provide for 1 ton of ground limestone (or its equivalent in hydrated lime) every 6 years, 480 pounds of 16 per cent superphosphate and 160 pounds of muriate of potash every 3 years, and 160 pounds of nitrate of soda annually. This or an equivalent treatment is recommended for Massachusetts conditions.

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APPENDIX

TABLE 3—TREATMENTS OF EXPERIMENT A

Plot	1921	1922	1927	1928	1921 East half of plot	1927 West half of plot
1	P	P	2K	Nothing	L	L
2	N, P	N, P	2K	2N	L	L
3	Check	Check	Check	Check	L	Check
4	N, P, K	N, P, K	2K	2N	L	L
5	P, K	P, K	2K	Nothing	L	L

N—Chilean nitrate of soda.....160 pounds per acre
P—superphosphate (16% P_2O_5).....180 pounds per acre
K—muriate of potash..... .....80 pounds per acre
L—ground limestone.....1600 pounds per acre
Check—nothing added

TABLE 4—YIELDS OF GRASS FROM EXPERIMENT A, 1928
(Pounds per acre of dry matter.)

Plot	1st CUTTING		2nd CUTTING		TOTAL		Excess of east over west half
	East half	West half	East half	West half	East half	West half	
1	1468	1274	1517	1119	2985	2393	612
2	3006	2960	1767	1338	4773	4298	475
3	1028	577	1070	437	2098	1014	1084
4	3034	2974	1655	1077	4689	4051	638
5	1883	1130	1433	1192	3316	2322	994

Note—All dry matter determinations and fodder analyses reported in this bulletin were made in the Feed Control Laboratory under the direction of Philip H. Smith.

TABLE 5.—YIELDS OF PROTEIN FROM EXPERIMENT A, 1928
(Percentages and pounds per acre)

Plot	1st CUTTING				2nd CUTTING				TOTAL		Excess of east over west half
	East half		West half		East half		West half		East	West	
	%	Lbs.	%	Lbs.	%	Lbs.	%	Lbs.	Lbs.	Lbs.	Lbs.
1	12.4	182	14.2	181	13.7	208	14.0	157	390	338	52
2	13.0	391	11.9	352	13.9	246	13.8	185	637	537	100
3	12.4	127	10.1	58	13.0	139	11.7	51	266	109	157
4	13.7	416	11.1	330	13.7	227	13.4	144	643	474	169
5	15.1	284	12.5	141	14.1	202	12.2	146	486	287	199

TABLE 6.—TREATMENTS OF EXPERIMENT B

Plot	Fertilizer treatment	Plot	Fertilizer treatment	Plot	Fertilizer treatment
1	P	5	2K	9	2P, 2K
2	K	6	Check	10	Check
3	Check	7	Gypsum	11	P, K, N
4	2P	8	P, K		

Lime was applied to east half of each plot twice, 1921-22 and 1928.

N—Chilean nitrate of soda ..... 160 pounds per acre
P—superphosphate (16% P_2O_5)..... 480 pounds per acre
K—muriate of potash..... 80 pounds per acre
Gypsum..... 480 pounds per acre
Lime, as ground limestone..... 2400 pounds per acre
Check—nothing added

Each treatment was replicated 6 times, making 66 plots (1 rod x 2 rods) in 6 series. Dates of application of fertilizer were as follows:

Series III: S 1922, S 1923, S 1926, S 1930
Series IV: F 1921, S 1923, S 1927*, S 1930 } 4 applications

Series I: S 1922, S 1923, S 1927*, S 1928, S 1930
Series VI: F 1921, S 1923, S 1927*, S 1928, S 1930** } 5 applications

Series II: F 1921, S 1923, S 1924, S 1925, S 1926, S 1930
Series V: S 1922, S 1923, S 1924, S 1925, S 1928, S 1930** } 6 applications

S—Spring F—Fall

*In 1927 all treatment consisted of muriate of potash (160 pounds per acre) applied to all plots of Series I, IV and VI, except the check plots (3, 6 and 10); and nitrate of soda (160 pounds per acre) to plot 11 of the same series.

**By mistake plot 10 of Series V and VI received fertilizer which should have gone to plot 11.

TABLE 7.—PERCENTAGE RATING OF PLOTS OF EXPERIMENT B, JUNE, 1923

Series I, II, III, V, and VI

Plot	Fertilizer Treatment	Lime	No lime
1	P	25	12
2	K	53	28
3	Check	32	17
4	2P	26	15
5	2K	61	30
6	Check	31	13
7	Gypsum	28	21
8	P, K	61	39
9	2P, 2K	72	47
10	Check	47	23
11	P, K, N	57	35

TABLE 8.—YIELD AND CHEMICAL COMPOSITION OF ONE CLIPPING OF GRASS FROM EXPERIMENT B, 1923

(Pounds per acre and percentages.)

Plot	Fertilizer treatment	DRY MATTER		PROTEIN				ASH	
		Lime	No lime	Lime		No lime		Lime	No lime
		Lbs.	*Lbs.*	%	*Lbs.*	%	*Lbs.*	%	%
1	2P	1050	863	18.7	196	14.2	122	8.10	7.46
5	2K	1023	676	23.3	238	20.8	140	8.79	8.85
6	Check	766	703	18.0	138	14.6	103	7.55	6.51
9	2P, 2K	1576	1272	24.5	387	20.6	262	8.81	8.77

TABLE 9.—BOTANICAL ANALYSIS OF CLIPPINGS FROM EXPERIMENT B, 1929

Average of Series I-VI

Plot	Fertilizer treatment	LIME			NO LIME		
		Grass	Clover	Weeds	Grass	Clover	Weeds
		%	%	%	%	%	%
1	P	93	5	2	95	3	2
2	K	88	9	3	92	6	2
3	Check	93	4	3	93	3	4
4	2P	93	6	1	97	2	1
5	2K	82	17	1	94	4	2
6	Check	92	7	1	96	3	1
7	Gypsum	92	7	1	93	6	1
8	P, K	95	4	1	95	4	1
9	2P, 2K	90	9	1	92	7	1
10	Check	95	3	2	92	3	5
11	P, K, N	85	13	2	82	17	1
	Average of Checks	93	1	2	94	3	3

TABLE 10.—YIELD OF CLIPPINGS FROM EXPERIMENT B, MAY 21, 1930

(Pounds of dry matter per acre.)

Plot	Fertilizer treatment	I	II	III	IV	V	VI	Average
		LIME SERIES						
1	P	944	894	340	630	690	368	644
2	K	780	706	385	673	857	600	667
3	Check	628	456	305	686	811	692	596
4	2P	582	417	216	808	814	561	566
5	2K	600	127	378	739	717	889	625
6	Check	768	286	481	853	699	697	614
7	Gypsum	127	197	425	457	481	408	399
8	P, K	570	371	483	819	494	763	583
9	2P, 2K	590	369	274	606	727	702	544
10	Check	758	351	431	832	699	1111	593*
11	P, K, N	1031	902	1495	1253	872	704	1170*
	Average	698	489	474	760	706	673	
		NO-LIME SERIES						
1	P	920	248	428	159	159	644	425
2	K	968	703	532	252	264	268	498
3	Check	421	375	796	439	284	554	478
4	2P	556	585	422	332	261	754	486
5	2K	717	439	168	212	197	668	400
6	Check	416	350	348	326	272	498	318
7	Gypsum	524	388	494	307	100	724	423
8	P, K	448	501	487	231	206	403	388
9	2P, 2K	518	458	686	878	197	463	533
10	Check	471	496	194	218	719	1067	346*
11	P, K, N	748	872	1079	741	327	742	861*
	Average	610	493	512	376	589	410	

*Average of Series I-IV, only.

TABLE 11.—YIELD OF CLIPPINGS FROM EXPERIMENT B, 1930.

Average of Series I-VI

Plot	Fertilizer treatment	LIME		NO LIME		Difference due to lime
		Dry matter per acre	Deviation from check	Dry matter per acre	Deviation from check	
1	P	644	+48	425	-53	+219
2	K	667	+71	498	+20	+169
3	Check	596	.....	478	.....	+118
4	2P	566	-30	486	+8	+80
5	2K	625	+11	400	+82	+225
6	Check	614	.....	318	.....	+296
7	Gypsum	399	-215	423	+105	-24
8	P, K	583	-21	388	+56	+195
9	2P, 2K	544	-51	533	+187	+11
10	Check	593*	.....	346*	.....	+147
11	P, K, N	1170*	+577	861*	+515	+309

*Series I-IV, only.

Note—By mistake Plot 10 of Series V and VI received fertilizer which should have gone to Plot 11 in 1930.

TABLE 12.—PERCENTAGE OF CLOVER IN SERIES I, EXPERIMENT B, 1929 AND 1930

Plot	Fertilizer treatment	1929		1930	
		Lime	No lime	Lime	No lime
1	P	13	3	trace	trace
2	K	15	19	1	2
3	Check	5	8	1	trace
4	2P	20	4	trace	3
5	2K	26	5	3	trace
6	Check	5	10	1	trace
7	Gypsum	16	11	1	trace
8	P, K	11	12	1	trace
9	2P, 2K	22	11	trace	trace
10	Check	5	3	trace	trace
11	P, K, N	27	47	trace	trace

TABLE 13.—PERCENTAGE OF CERTAIN NUTRIENTS IN CLIPPINGS FROM EXPERIMENT B, 1930

(Per cent of dry weight)

Plot	Fertilizer treatment	PROTEIN		PHOSPHORIC ACID		CALCIUM OXIDE	
		Lime	No lime	Lime	No lime	Lime	No lime
1	P	12.8	12.6	.89		.88	.62
2	K	13.4	12.5			.84	.71
4	2P	12.9	13.5	.71		.86	.64
5	2K	13.8	12.5			.77	.45
7	Gypsum	12.8	13.4			.99	.73
8	P, K	12.8	12.9	.83		.86	.66
9	2P, 2K	12.6	14.2	.86		.83	.62
11	P, K, N	16.8	19.3	.76		.86	.63
All Check Plots		13.0	12.6	.70		.88	.69

Note—Determinations of phosphoric acid and calcium oxide were made in the Fertilizer Control Laboratory, under the direction of H. D. Haskins.

TABLE 14.—TREATMENTS OF EXPERIMENT C

Plot	Treatment	Plot	Treatment	Plot	Treatment
1	K	11	2L, 2P	21	3L, 3K
2	P	12	2P, 2K	22	3L, 3P, 3K
3	L	13	2L, 2K	23	2K, Seed
4	L, P	14	2L, 2P, 2K	24	2P, Seed
5	P, K	15	Check	25	2L, Seed
6	L, K	16	3K	26	2L, 2P, Seed
7	L, P, K	17	3P	27	2P, 2K, Seed
8	2K	18	3L	28	2L, 2K, Seed
9	2P	19	3L, 3P	29	2L, 2P, 2K, Seed
10	2L	20	3P, 3K	30	Check, Seed

K— 108 lbs. muriate of potash per acre
2K— 216 lbs. muriate of potash per acre
3K— 432 lbs. muriate of potash per acre
Check—Nothing added
L— 1740 lbs. ground limestone per acre
2L— 3480 lbs. ground limestone per acre
3L—10875 lbs. ground limestone per acre
P— 435 lbs. superphosphate (16% P_2O_5) per acre
2P— 1740 lbs. superphosphate (16% P_2O_5) per acre
3P— 5220 lbs. superphosphate (16% P_2O_5) per acre

Mineral treatments were applied in 1924 and 1929. In 1929 and 1930, the east half of each plot was given nitrogen as Chilean nitrate of soda at the rate of 30 lbs. N per acre. Size of plots 10 ft. x 10 ft.

TABLE 15.—YIELD PER ACRE OF GRASS AND CLOVER, EXPERIMENT C, 1929

Plot	DRY MATTER (total)		BOTANICAL ANALYSIS Grasses		Clovers		GRASSES AND CLOVERS	
	No N	N	No N	N	No N	N	No N	N
	Lbs.	*Lbs.*	*%*	*%*	*%*	*%*	*Lbs.*	*Lbs.*
1	527	919	67	72	0	18	353	827
2	1770	1585	20	79	trace	1	354	1268
3	1436	1953	66	53	29	37	1364	1758
4	752	2070	62	96	22	1	632	2008
5	1065	1764	72	74	1	20	777	1658
6	771	1501	71	81	2	trace	563	1216
7	421	1329	87	66	1	31	370	1289
8	1343	1361	60	72	3	0	846	980
9	476	1075	85	97	3	0	419	1043
10	516	1946	89	93	0	3	459	1868
11	922	1607	83	92	8	4	839	1543
12	1002	1086	88	92	trace	3	882	1032
13	921	1530	73	88	21	6	866	1438
14	416	1037	85	73	1	16	358	923
15	242	902	3	52	0	0	7	469
16	1009	1997	35	93	0	trace	353	1857
17	771	1439	93	95	0	trace	717	1367
18	617	1095	89	97	1	0	555	1062
19	482	922	95	97	1	1	463	904
20	703	1503	89	96	0	trace	626	1443
21	2145	2638	89	88	10	12	2124	2638
22	2587	2477	63	41	37	59	2587	2477
23	1429	1305	69	84	5	0	1057	1096
24	911	1322	91	84	trace	5	829	1177
25	916	1540	88	100	5	0	852	1540
26	1322	1564	78	89	14	7	1216	1501
27	800	1952	75	85	21	9	768	1835
28	1050	1853	74	91	20	4	987	1760
29	1144	2849	69	93	21	3	1030	2735
30	771	609	20	45	0	2	154	286

TABLE 16.—YIELD PER ACRE OF GRASS AND CLOVER, EXPERIMENT C, 1930

Plot	FIRST CLIPPING, June 5								SECOND CLIPPING, July 28								TOTAL YIELDS			
	Dry Matter (total)		Botanical Analysis Grasses		Botanical Analysis Clovers		Grasses and Clovers		Dry Matter (total)		Botanical Analysis Grasses		Botanical Analysis Clovers		Grasses and Clovers		Dry Matter (total)		Grasses and Clovers	
	No N	N	No N	N	No N	N	No N	N	No N	N	No N	N	No N	N	No N	N	No N	N	No N	N
	Lbs.	*Lbs.*	*%*	*%*	*%*	*%*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*%*	*%*	*%*	*%*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	81	735	81	95	0	0	68	698	137	436	65	89	0	1	89	353	221	1171	157	1051
2	205	545	82	94	0	trace	168	512	209	363	60	71	9	trace	111	258	414	908	312	770
3	93	719	72	96	20	trace	86	690	351	508	16	86	46	7	323	172	444	1227	409	1162
4	67	772	72	99	trace	0	48	764	82	377	30	83	13	7	60	339	149	1149	108	1103
5	38	456	63	90	0	0	24	410	102	527	81	88	0	2	83	474	140	983	107	884
6	69	583	93	93	0	3	64	569	203	419	17	81	47	12	191	390	272	1002	255	959
7	145	510	89	89	trace	1	129	486	338	273	48	63	17	31	321	265	483	813	450	751
8	207	973	82	97	0	trace	170	944	108	333	62	68	0	0	67	226	315	1306	237	1170
9	155	716	77	96	0	0	119	687	60	292	87	80	0	0	52	234	215	1008	171	921
10	90	672	93	98	0	trace	81	659	31	337	77	84	0	9	24	303	121	1009	108	962
11	122	347	84	88	1	trace	104	305	142	127	15	69	50	10	135	169	264	474	239	405
12	342	716	95	99	0	trace	325	709	69	354	82	43	2	51	58	333	411	1070	383	1042
13	201	682	98	98	2	0	201	668	61	244	71	78	5	11	48	217	265	926	252	885
14	293	457	81	78	5	10	252	402	101	227	41	51	48	41	90	209	394	684	342	611
15	52	513	56	98	0	0	29	532	67	294	40	86	0	0	27	253	119	837	56	785
16	127	638	88	99	0	trace	112	632	76	133	73	86	0	0	55	114	203	771	167	746
17	176	763	89	100	0	0	157	763	66	194	81	98	0	0	53	190	242	957	210	953
18	185	814	90	97	0	0	167	787	41	267	89	83	4	0	38	222	226	1078	205	1009
19	123	1188	94	98	0	trace	116	1164	38	379	70	73	9	12	30	322	161	1567	146	1486
20	272	725	99	98	0	2	269	725	137	403	93	96	0	2	127	395	409	1128	396	1120
21	244	910	88	99	12	trace	244	901	297	456	65	86	22	12	258	447	508	1366	469	1348
22	484	1226	68	78	32	19	484	1189	641	949	45	48	55	52	641	949	1125	2175	1125	2138
23	372	948	95	95	0	0	353	872	132	119	86	95	2	0	116	142	504	1067	469	1014
24	63	672	89	94	0	0	56	632	118	136	62	93	0	0	73	126	181	808	129	758
25	195	681	97	98	0	trace	189	667	99	244	69	99	1	7	69	237	294	925	219	994
26	344	658	93	99	1	trace	292	651	268	299	38	76	12	24	244	299	579	957	506	950
27	309	772	94	96	1	1	285	749	89	512	19	53	57	43	86	492	389	1284	371	1241
28	167	788	98	96	0	trace	164	756	227	514	48	84	38	11	195	488	394	1302	359	1244
29	407	753	96	94	4	4	395	738	355	383	47	57	50	38	341	364	762	1136	739	1102
30	101	345	71	53	0	0	72	167	238	159	27	63	0	0	64	95	339	465	136	262

TABLE 17.—AVERAGE YIELD OF GRASS AND CLOVER FROM PLOTS OF EXPERIMENT C WHICH RECEIVED MEDIUM APPLICATIONS OF FERTILIZER

Treatment	Plot	DRY MATTER PER ACRE, POUNDS					
		1929		1930		Average	
		No N	N	No N	N	No N	N
2K	8, 23	952	1038	353	1091	653	1065
2P	9, 24	624	1110	150	840	387	975
2L	10, 25	656	1704	179	933	418	1319
2L, 2P	11, 26	1028	1522	373	678	701	1100
2P, 2K	12, 27	825	1434	377	1142	601	1288
2L, 2K	13, 28	927	1599	306	1065	617	1332
2L, 2P, 2K	14, 29	694	1829	541	857	618	1343
Check	15, 30	81	378	96	524	89	451

TABLE 18.—RATIO OF YIELDS FROM NO-NITROGEN AND NITROGEN PLOTS

First and Second Clippings, Experiment C, 1930

Plot	FIRST CLIPPING June 5	SECOND CLIPPING July 28	TOTAL YIELD
	No N : N	No N : N	No N : N
1	1 : 8.8	1 : 3.2	1 : 5.3
2	1 : 2.7	1 : 1.7	1 : 2.2
3	1 : 7.7	1 : 1.4	1 : 2.8
4	1 : 11.5	1 : 4.6	1 : 7.7
5	1 : 12.0	1 : 5.2	1 : 7.0
6	1 : 8.4	1 : 2.1	1 : 3.7
7	1 : 3.7	1 : 0.8	1 : 1.7
8	1 : 4.7	1 : 3.1	1 : 4.1
9	1 : 1.6	1 : 4.9	1 : 4.7
10	1 : 7.5	1 : 10.9	1 : 8.3
11	1 : 2.8	1 : 0.9	1 : 1.8
12	1 : 2.1	1 : 5.1	1 : 2.6
13	1 : 3.3	1 : 4.0	1 : 3.5
14	1 : 1.6	1 : 2.2	1 : 1.7
15	1 : 10.4	1 : 4.4	1 : 7.0
16	1 : 5.0	1 : 1.8	1 : 3.8
17	1 : 4.3	1 : 2.9	1 : 4.0
18	1 : 4.4	1 : 6.5	1 : 4.8
19	1 : 9.7	1 : 10.0	1 : 9.7
20	1 : 2.7	1 : 2.9	1 : 2.8
21	1 : 4.3	1 : 1.5	1 : 2.7
22	1 : 2.5	1 : 1.5	1 : 1.9
23	1 : 2.5	1 : 1.1	1 : 2.1
24	1 : 10.7	1 : 1.2	1 : 4.5
25	1 : 3.5	1 : 2.5	1 : 3.1
26	1 : 2.1	1 : 1.1	1 : 1.7
27	1 : 2.6	1 : 5.8	1 : 3.3
28	1 : 1.7	1 : 2.3	1 : 3.3
29	1 : 1.9	1 : 1.1	1 : 1.5
30	1 : 3.1	1 : 0.6	1 : 1.9

TABLE 19.—DRY MATTER AND PROTEIN IN TOTAL CLIPPINGS FROM EXPERIMENT C, 1930

Plot	DRY MATTER PER ACRE			PROTEIN		PROTEIN PER ACRE		
	No N	N	Ratio No N : N	No N	N	No N	N	Ratio No N : N
	Lbs.	*Lbs.*		%	%	*Lbs.*	*Lbs.*	
1	221	1171	1 : 5.3	10.8	17.5	24	205	1 : 8.5
2	414	908	1 : 2.2	12.1	13.0	50	118	1 : 2.4
3	444	1227	1 : 2.8	20.4	16.4	91	201	1 : 2.2
4	149	1151	1 : 7.7	16.1	14.3	24	165	1 : 6.9
5	140	983	1 : 7.0	10.3	13.3	14	131	1 : 9.4
6	272	1002	1 : 3.7	16.3	14.9	44	149	1 : 3.4
7	483	813	1 : 1.7	17.2	10.5	83	85	1 : 1.0
8, 23	410	1187	1 : 2.9	14.9	12.8	61	152	1 : 2.5
9, 24	198	908	1 : 4.6	10.3	12.6	20	114	1 : 5.7
10, 25	208	967	1 : 4.6	11.1	13.4	23	130	1 : 5.7
11, 26	422	716	1 : 1.7	14.8	13.6	63	97	1 : 1.5
12, 27	400	1177	1 : 2.9	11.5	15.0	46	177	1 : 3.8
13, 28	330	1114	1 : 3.4	10.9	13.3	36	148	1 : 4.1
14, 29	578	910	1 : 1.6	12.9	14.5	75	132	1 : 1.8
15, 30	179	651	1 : 3.6	9.9	10.3	18	67	1 : 3.7
16	203	771	1 : 3.8	10.0	12.4	20	96	1 : 4.8
17	242	957	1 : 4.0	10.0	11.5	24	110	1 : 4.6
18	226	1078	1 : 4.8	9.8	13.0	22	140	1 : 6.4
19	161	1566	1 : 9.7	9.6	12.6	16	197	1 : 12.3
20	409	1128	1 : 2.8	9.7	13.2	40	149	1 : 3.7
21	508	1366	1 : 2.7	13.5	14.9	69	204	1 : 3.0
22	1125	2175	1 : 1.9	19.7	21.1	222	459	1 : 2.1

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE

5M-3-32. No. 4887

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 282 MAY, 1932

Relation Between Egg Quality and Price

By Adrian H. Lindsey and Hubert W. Yount

In order that the poultryman may feel justified in placing special emphasis on the quality of eggs and secure in making the extra expenditure involved in producing a higher grade product, he should have some assurance that quality values are recognized by the consumer. This study is an attempt to discover the relationship between quality and price of eggs as found on the retail market.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

SUMMARY

1. Prices were related to weight under practically all conditions. This is the most definite and significant relationship found in the correlation analysis.

2. The combined effect of all quality factors on price was most significant in August and least significant in April.

3. The relative seasonal effect of the individual quality factors on price was as follows:

Weight was most significant in August, least in November.
Air space was most significant in November, least in April.
Condition of yolk was most significant in April, least in November.
Condition of white was most significant in August, least in April.

4. Average quality varied with price throughout the lower and middle price ranges only.

5. The range in quality *within* each price range varied so widely that price could not be used as a criterion of quality.

6. Dirty eggs affected price more than variations in color within each dozen.

7. Range in weight of eggs within each dozen had very little relation to price.

8. The average quality of eastern eggs was invariably higher than the quality of western eggs.

9. There was little to be gained in purchasing labeled eggs, because within each brand the quality and weight varied as widely in relation to price as was true of unbranded eggs.

RELATION BETWEEN EGG QUALITY AND PRICE

By Adrian H. Lindsey, Professor of Agricultural Economics, and Hubert W. Yount[1]

INTRODUCTION

The Problem

Market information dealing with egg prices usually stresses the factors of supply, such as receipts and storage holdings, while little space is given to quality. The price of eggs at any given time is determined by a number of factors, among which are the supply and demand factors commonly considered. For any individual store and in many cases for individual producers or shippers, the quality of eggs placed upon the market with respect to the average quality of the grade may have as much effect on price at the time of sale as the influences affecting the general price level of the grade, which are supply and demand factors.

Egg grades are based on certain external and internal characteristics which have been found to have an influence in determining the price among the members of the wholesale trade. Attempts by the extension services of the New England States to carry the idea of quality to the consumer through building up consumer recognition of grades and their identifying marks such as labels and trade names have failed to meet with marked success, either because consumers as a class fail to understand the factors entering into a good grade of eggs versus a bad grade, or because the factors which supervisory authorities have considered in making up the grades are not the factors really considered by consumers in buying eggs. No attempt has previously been made to determine the relative importance of the factors entering into the several grades established by state authorities. Extension specialists in approaching producers with a marketing program have specified certain qualifications for eggs which may or may not be the particular qualifications demanded by consumers, particularly those for which the consumer is willing to pay a premium over the average price.

As a result of these observations the study was undertaken to answer the question as to what quality factors consumers were willing to pay for. It is doubtful, however, whether the study completely answers this question. The method of purchasing eggs from retail stores in cartons or by telephone gives the consumer very little opportunity to judge whether the eggs are of sufficient quality to justify the price asked. In such instances the consumer must and does depend upon the retailer to deliver a dozen eggs of good quality. If she continues to buy eggs from this store or continues to purchase the same grade, it may be assumed that she is either ignorant of what constitutes quality, or satisfied with what she has received, price considered.

The producer, as well as the consumer, should be interested in knowing whether price is a criterion of quality. The methods used in securing the data, by comparing prices paid with quality of each dozen purchased, should tell

[1]Mr. Yount, formerly Assistant Professor of Agricultural Economics, initiated the project, directed the collection of data, and completed some of the correlation analyses.

whether there is any relationship between quality and price. The study will also determine the extent to which these quality factors affect price and the relative importance of each, if statistical measures are applied.

The method used in the study was to purchase eggs at retail from a selected sample of stores representative of the consuming areas in Massachusetts. At each store visited a purchase was made consisting of one dozen of each grade of eggs sold by that store. Each sample was given a number and a form was filled out giving data concerning the type of store, the name of the grade, the price for which it was sold, and other identifying information. The samples were taken immediately to a central point where they were candled by an egg specialist. They were weighed and the external characteristics noted.

In order to correct for seasonal conditions, samples were collected at three different times during the year: first, during the period of highest prices in November; second, during April when receipts of eggs in all the central markets were heavy and the average quality was high; third, in August, when current receipts were low and the quality of production was also low, due to temperature and methods of handling. The first sample was taken in November, 1928, in the cities of Springfield, Worcester and Boston, while the samples collected in April and August (1929) were confined to the metropolitan area in and around Boston.

Quality Factors Considered

An attempt was made to obtain a measure of every quality factor that might have any influence on price. The factors considered were as follows:

I. External

a. Appearance—clean or dirty
b. Color
c. Number of broken eggs, crax or leakers
d. Weight of eggs—net weight per dozen
e. Range in weight

II. Internal

a. Shrinkage as indicated by air space
b. Condition of yolk
c. Condition of white
d. Inedibles—such as rots, stuck yolks, blood and meat spots

Method of Indicating Quality

For each dozen of eggs purchased a data sheet was filled out similar to that in Figure 1. External characteristics were indicated by count and internal measurement. Thus, on appearance the number of dirty eggs was indicated. On color the number of eggs of the less important color was noted. On uniformity the range in weight between the largest and smallest egg was noted. The net weight was indicated by weighing the eggs as sold in the carton and deducting the weight of the carton.

In indicating the internal quality the factors were graded into classes. Thus, air space was divided into five classes as follows:

Class	*Inches*
1	0 - 1/16
2	1/16 - 1/8
3	1/8 - 1/4
4	1/4 - 3/8
5	3/8 and over

On condition of the yolk three grades were used.

Class	*Grade*
1	Not visible
2	Slightly visible
3	Clearly visible

Condition of the white was indicated by three grades also.

Class	*Grade*
1	Firm and clear
2	Reasonably firm
3	Weak and watery or worse

An example of the scoring for each internal quality factor is shown in Figure 1 under the candling record. From these records a score was made for each dozen on the basis of adding the figures for individual eggs. Variations in these scores were indicative of differences between individual dozens with respect to each of the qualities considered.

The external score was computed by deducting 1¼ points for each dirty egg and 2 points for each egg differing in color from the majority. Uniformity was scored as follows:

Range in Weight (ounces)	*Points off*
5	1
6	2
7	4
8	6
9	9
10	12
11	15
12	18

Net weight per dozen was scored on the basis of a weight of less than 24 ounces. No attempt was made to score eggs of more than 24 ounces. The method of scoring was as follows:

Weight per dozen	*Points off*
23	1
22	2
21	6
20	12
19	20
18	30

A deduction of 10 points was made for each broken egg.

The external score of the dozen in Figure 1 was figured as follows: 3 and ¾ points for the 3 dirty eggs, 4 points for the 2 white eggs in the brown dozen, 6

No. 24

City Boston — Date 8/29/29

Section Back Bay

Name of Firm —

Street Address —

1. Type of Store

Cash and Carry ✓	Chain ✓	General Market
Credit and Delivery	Private	Neighborhood

2. Business _____ Residential, G ✓ A _____ P _____

3. Refrigeration: Full _____ Part ✓ None _____

4. Eggs Brand Fancy XXXX Advertised Grade Selected Fresh

a. Selling Grade
Nearby
1 65 cents
2

Eastern
1

Western
1
2

b. Cartoned
Bulk

c. Weight
Gross 25
Tare 2
Net 23

d. Range in Weight 20-28

e. Number of
White eggs 2
Irregular shape
Dirties 3

5. Candling Record

a. Air Space (5)				b. Condition of Whites (3)				c. Condition of Yolks (3)			
3	3	2	2	2	2	2	2	2	1	2	2
2	3	3	3	2	2	3	3	1	1	2	3
2	2	2	2	1	1	2	2	1	1	2	2
Score 29				Score 24				Score 20			

d. Germ Development
Developed

e. Inedibles
Before laying
From handling

f. Number of Cracks

Figure 1. Data Sheet for One Dozen Eggs.
Showing type of information obtained and method of scoring.

points for the range of 8 ounces between the size (per dozen) of the smallest and the largest eggs, and an additional point because the weight lacked one ounce of being a full 24-ounce dozen. Thus it may be seen that in the case of both the internal scores and the external scores the higher the score the poorer the quality of the eggs.

Method of Analysis

The individual data sheet as illustrated by Figure 1 and the above scoring method made it possible to obtain a score for each individual quality factor and a final or total external, and internal, quality score for each dozen. In order to evaluate the importance of these four factors, the records were first sorted by general grade, whether eastern, western or cold storage, and by type of store as between private and chain. The purpose of this split was to eliminate basic differences in retailing methods between private and chain stores as one factor in price differences, as well as to eliminate broad grade differentials as between nearby and western or cold storage eggs. This analysis was made separately for the sample collected in each of the three periods in order to obtain a further check on the relative importance of each factor at different seasons of the year.

Tabular analyses were made to discover the simple relationships between average quality and price for eastern and western eggs in chain and private stores. Multiple correlation analyses were made for both external factors and internal factors in order to determine the influences which each of the various quality factors had on price under all conditions.

TABULAR ANALYSIS[2]

Simple analysis was made by the use of tables to determine the variation of prices between stores for the same and for different qualities of eggs. These tables should tell whether price may be used as a criterion of quality. In other words, can a consumer depend upon price paid to insure quality?

In this analysis the store and egg grade relationships are used, as indicated previously. Weights are given in ounces. It should be kept in mind at all times when considering interior quality scores that the lower the score, the better the egg. The final scoring includes air cell, condition of white and condition of yolk. In order to gain a better conception of the meaning of interior scores examples may be cited. The best dozen of eggs purchased scored 41 and the poorest, a dozen of cold storage eggs, scored 129. The poorest "fresh" dozen scored 120.

April Eggs

The extreme range of prices paid for eggs in April was from 30 to 65 cents. (Table 1). The most frequent prices paid were 33, 39, 45 and 55 cents, with 45 cents the most common. It was in the April group that the best and the poorest dozens of fresh eggs were found. Two dozen eggs scored 41 each. One of these dozen had perfect white and yolks, and only five eggs out of the dozen had air cells larger than one-sixteenth inch. This dozen sold for 55 cents. The other dozen scoring 41 sold for 49 cents. The poorest dozen of eggs scoring 120 sold at 39 cents. In this dozen, nine eggs had weak and watery whites and clearly visible yolks, one of which was stuck. The air cells were all over one-fourth inch and 7 were over three-eighths inch. This latter dozen was branded[3] eggs.

[2]Prices in the following tables are in cents per dozen. Frequencies represent number of dozens at given prices. The method of indicating quality scores is described on pages 4 and 5.

[3]Branded eggs will be used to indicate labeled or trade marked eggs.

TABLE 1.—PRICE RANGE AND FREQUENCY TABLE, APRIL EGGS

Price per dozen (cents)	Frequencies[1]				
	Chain Western	Private Western	Chain Eastern	Private Eastern	Total
30	....	....	....	1	1
31	7	....	....	..	7
32	3	1	....	..	4
33	17	1	....	....	18
34	1	..	....	....	1
35	5	5	..	....	10
37	2	..	....	....	2
38	2	3	....	....	5
39	16	5	....	1	22
40	5	5	....	..	10
41	4	....	2	..	6
42	....	1	....	1	2
43	1	3	1	2	7
44	2	1	....	....	3
45	7	9	3	6	25
46	1	..	3	..	4
47	7	1	3	1	12
48	1	3	..	3	7
49	1	2	2	6	11
50	..	....	3	10	13
51	...	.	1	2	3
52	..	.	..	1	1
53	.		2	6	8
54	....		....	1	1
55	....	.	5	14	19
56	....		..	1	1
57	....	....	....	1	1
58	....	....	....	2	2
59	....	....	1	2	3
60	....	....	....	3	3
65	....	....	..	5	5
Total	82	40	26	69	217

[1]Number of dozens at given prices.

Eastern Eggs

Chain stores sell very few eastern eggs in relation to western eggs in April, and prices vary widely. The range in price was from 41 to 55 cents, with 45 to 50 cents most frequently paid. (Table 1). In Table 2 it will be seen that prices advance with weight up through the 50-54 cent price range. The heaviest dozen, however, was sold at 47 cents. Price increased as air space decreased but fresher eggs were purchased at 49 cents than in the 50-54 cent range.

Eastern eggs in private stores sold most frequently at 55 cents with a range of from 30 cents to 65 cents. There was no advantage in weight to be gained by paying more than 54 cents. Eggs purchased for more than 54 cents were generally lower in quality than in the 50-54 cent group.

Western Eggs

Among western eggs sold in chain stores the prices reflected the quality very well. There was considerable variation within the groups, but average weights and freshness increased as prices increased.

TABLE 2.—WEIGHT AND QUALITY SCORES, APRIL EGGS

Price per dozen (cents)	Frequencies	Weight (ounces)		Air Space		Final Internal Score	
		Range	Average	Range	Average	Range	Average
			Chain Eastern				
Under 45	3	19½-25	22½	39-45	43	78-89	82
45-49	11	23½-29½	25½	20-40	35	55-89	77½
50-54	6	21 -27	25	32-42	36	71-87	79
55-59	6	24½-26	25	27-33	31	58-78	67
Total	26	19½-29½	24	27-45	36	55-89	76
			Private Eastern				
Under 45	5	21 -23½	22	29-44	35	61-88	75
45-49	16	23½-26	24½	13-43	29	41-89	66
50-54	20	22½-27½	25	14-38	25	44-87	59
55-59	20	22 -27	25	16-37	28	41-79	64
60-65	8	24 -26	25	19-36	27	46-73	62
Total	69	21 -27½	24	13-44	28	41-89	65
			Chain Western				
30-34	28	21 -25	23	26-52	41	60-108	85
35-39	25	19½-25½	24	29-55	39	60-120	81
40-44	12	23 -28	24½	21-54	37½	52-101	78
45-49	17	23 -26	24½	29-44	36	58- 92	74
Total	82	19½-28	24	21-55	38	52-120	79
			Private Western				
Under 40	15	21½-26	23½	30-44	37	57- 93	77
40-44	10	22 -25	23½	29-51	36	61- 89	72
45-49	15	23 -26	24½	22-48	36	53- 89	75
Total	40	21½-26	24	22-51	36.3	53- 93	75

Price ranges among western eggs were similar to those of eastern eggs. The range for chain stores was 31-49 cents and for private stores 32-49 cents. The most frequent sales were made at 33 cents and 39 cents for chain stores, and 45 cents for private stores.

It will be seen here, as well as later, that among private stores higher premiums do not necessarily guarantee higher quality eggs. Weight was often reflected in the higher price paid but interior quality was not necessarily better.

August Eggs

Differences in quality were more pronounced in August than in April. Naturally the price range was greater. The extreme range for all grades was from 35 cents to 87 cents, or 52 cents as compared with 39 cents for April. A few dozen cold storage eggs were purchased but the number was not sufficient to use as a basis for analysis.

Eastern Eggs

Prices paid for eastern eggs ranged from 51 to 79 cents, in the case of chain stores, and from 45 to 87 cents in privately owned stores. The most frequent price in the case of chains was 63 cents, and for private stores 75 cents. (Table 3).

Table 3.—Price Range and Frequency Table, August Eggs

Price per dozen (cents)	Frequencies[1]					
	Chain Storage	Chain Western	Private Western	Chain Eastern	Private Eastern	Total
35	....	2	....	....	....	2
36	1	....	....	....	....	1
38	1	1	....	....	....	2
39	....	1	2	....	....	3
40	1	1	2	....	....	4
41	3	26	3	....	....	32
42	....	....	1	....	....	1
43	....	1	1	....	....	2
45	1	....	2	....	1	4
46	....	....	....	....	1	1
48	2	1	2	....	2	7
49	....	2	1	....	....	3
50	1	....	5	....	....	6
51	....	13	....	3	....	16
52	1	1	2	....	....	4
53	....	1	....	2	....	3
55	....	1	4	1	4	10
57	....	....	1	....	....	1
58	....	....	....	1	....	1
59	....	2	1	....	1	4
60	....	....	1	1	2	4
62	....	....	....	....	1	1
63	....	3	1	24	....	28
65	....	....	....	3	4	7
68	....	....	....	....	1	1
69	....	....	....	1	1	2
70	....	1	....	....	....	1
72	....	....	....	....	1	1
73	....	....	....	1	4	5
75	....	....	....	7	14	21
77	....	....	....	1	2	3
78	....	....	....	....	4	4
79	....	....	....	2	1	3
80	....	....	....	....	6	6
85	....	....	....	....	4	4
87	....	....	....	....	1	1
Total	11	57	29	47	55	199

[1]Number of dozens at given prices.

Weight and quality were reflected in price up through the 75 cent group in eastern eggs sold in chain stores (Table 4). Nothing was gained by paying a premium over this amount. This was also true of private stores. It will be noted here that a 25-ounce egg with an internal score of 56 was purchased at an average price of 70 cents (66-75) in the chain stores and a 24½-ounce egg with the same interior quality at an average price of 77 (75-79) cents in the private store group. This margin between private and chain stores was the greatest for any time period, but the scores were almost identical with April. The average final score of the private-store eggs was 66 as against 75 for the chain. The private-store eggs were slightly fresher but not quite as heavy. It is important to note that eastern eggs had scores practically identical with April scores, whereas the August scores for western eggs were much higher. This observation indicates fairly conclusively the reason for the wide differential in price of eastern over western eggs in the late summer months.

Western Eggs

The range in price of western eggs in chain stores was from 35 to 70 cents, with one-half of the sales concentrated around 41 and 25 per cent around 51 cents. Weights showed considerable variation, especially in the lower-priced groups. Poorest eggs were found in the most frequently paid price groups, and better eggs were found in the higher-priced groups. Outside of these two groups, price advanced with quality and weight. In private stores price advanced with weight and quality except for the 45-49 cent group. The eggs in the latter were comparable in quality with the highest-priced group though 1½ ounces lighter in weight.

TABLE 4.—WEIGHT AND QUALITY SCORES, AUGUST EGGS

Price per dozen (cents)	Frequencies	Weight (ounces)		Air Space		Final Internal Score	
		Range	Average	Range	Average	Range	Average
			Chain Eastern				
55 or under	6	22½-24½	23½	32-48	39	74-108	90
56-65	29	22½-28	24	20-54	35	46-113	74
66-75	10	23½-25½	25	12-40	22	46- 74	56
76 or over	3	24 -25½	25	23-41	30	61- 89	71
Total	48	22½-28	21½	12-54	32½	46-113	75
			Private Eastern				
Under 54	4	21 -23	22	32-53	39	72-110	87
55-59	5	20½-24½	23	27-44	34	62- 92	75
60-64	3	24 -24½	24½	30-41	33	79- 92	84
65-69	14	22½-26	23	22-41	31	56-100	75
70-74	5	23½-26	24	22-42	29	58- 83	67
75-79	21	21½-27½	24½	13-28	21	42- 82	56
80-84	6	23½-26	24½	15-33	21	41- 70	57
85-89	5	25 -27	25½	13-33	23	44- 81	60
Total	63	20½-27½	24	13-53	27	42-110	66
			Chain Western				
35-39	4	19½-21½	20½	23-51	37	55-107	77
40-44	28	21 -24½	22½	28-55	44	76-117	97
45-49	3	21½-24	22	32-39	36	70- 96	81
50-54	16	22 -25½	23½	16-48	44	43-102	84
55-59	3	22½-23½	23	25-41	33	53- 95	76
60 or over	4	23½-25	24	19-33	28	53-78	65
Total	58	19½-25½	22	16-55	40	43-117	88
			Private Western				
39 or under	2	23 -23½	23	44-46	45	95- 99	97
40-44	7	20½-23½	22	27-58	42	72-119	92
45-49	5	22½-24	23	26-40	32	55- 90	72
50-54	7	22 -24	23	30-47	37	67-102	87
55-59	6	20 -24½	23½	25-48	34	71-116	83
60-64	2	23½-25½	24½	26-34	30	59- 86	73
Total	29	20 -25½	23	25-58	37	55-119	85

November Eggs

With peak prices of eggs occurring in November, it is natural that prices show the greatest range for this month. The extreme range was from 36 to 98 cents. However, considering only fresh eggs, as in the two previous cases, the range is from 48 to 98 cents, a variation of but 50 cents.

The data for this month are not so valuable because of the smaller number of dozens purchased. The introduction of storage eggs necessitates the division into six classes instead of four. It will be noted, also, that the percentage of western eggs purchased was very small. Western eggs comprised 20 per cent, eastern 45 per cent, and storage 35 per cent of the samples for November.

Storage Eggs

Prices of storage eggs ranged from 36 to 69 cents with the highest price found in a chain store. (Table 5). In both private and chain stores among storage eggs the weight increased as price increased. The lack of relationship between air space and interior quality would seem to prove that weight was a predominating factor in the price of storage eggs. (Table 6).

Table 5.—Price Range and Frequency Table, November Eggs

Price per dozen (cents)	Frequencies[1]						
	Chain Storage	Private Storage	Chain Western	Private Western	Chain Eastern	Private Eastern	Total
36	1	....	.	.			1
37	1	...	.	.			1
39	6	1					7
40	1	3	..			.	4
41	7						7
45	5	2	.		.	.	7
48	....			2	.	.	2
49	5	2	.	.			7
50	....	1	.	1	....	....	2
51	....	1		.	....	....	1
55	....	1	1	2	...	....	4
58	.	.	..	1		...	1
59	6		1	1	1	1	10
60	...	1	1	1		1	4
63	...	1			1		2
65	...	.		1	1	2	4
67			4		1	...	5
68				2	.	.	2
69	1		.	1	1	1	4
70	.		.	1		.	1
71				.	1	.	1
73					.	1	1
74			1	1	1		3
75				3		4	7
77			1				1
79			.		11	1	12
85			.		3	5	8
89					3	2	5
90			.		1	4	5
92				.	1	1	2
94					.	2	2
95					2	4	6
97					.	1	1
98						1	1
Total	33	13	9	17	28	31	131

[1] Number of dozens at given prices.

TABLE 6.—WEIGHT AND QUALITY SCORES, NOVEMBER EGGS

Price per dozen (cents)	Frequencies	Weight (ounces)		Air Space		Final Internal Score	
		Range	Average	Range	Average	Range	Average
			Chain Eastern				
Under 69	5	19½-24½	21½	35-57	42	74-117	87
70-74	2	22¾-26½	24½	33-50	41	77-103	90
75-79	11	23¼-25½	24½	36-52	42	75-106	89
80-84	0	. .	.	..	.		.. .
85-89	6	23¾-26	25	36-47	42	76-106	90
90-95	4	24¼-25½	25	37-43	30	78-102	86
Total	28	19½-26½	24	33-57	41	74-117	88
			Private Eastern				
59-68	4	20¼-24	22	20-50	35	54- 86	75
69-78	6	20 -24¾	23	29-51	42	64-108	87
79-88	6	22¼-25¼	23½	16-41	30	45- 77	68
89-98	15	21¾-26	24	19-47	29	43-105	66
Total	31	20 -26	23	16-51	34	43-108	74
			Chain Western				
Under 60	3	23¼-24½	24	44-45	44	86- 98	92
61-71	4	23½-25	24	44-50	47	89-112	100
72-77	2	25½	25½	35-36	35½	67- 85	76
Total	9	23½-25½	24½	35-50	42	67-112	89
			Private Western				
54 or under	3	21½-23¼	22	49-53	51	105-117	109
55-64	5	23 -25½	24	42-53	49	85-118	97
65-74	6	22¼-24¼	23½	34-52	45	84-103	93
75 or over	3	23 -23¾	23¼	38-52	45	97-101	98
Total	17	21¼-25½	23	34-53	47½	84-118	99
			Chain Storage				
Under 40	8	20½-28	22½	42-54	51	87-119	106
40-44	8	20 -24½	22½	46-60	53	93-129	108
45-49	10	20½-26	23	40-57	50	81-120	102
50 or over	7	22 -25¼	23½	51-57	53	96-112	105
Total	33	20 -28	23	40-60	52	81-129	105
			Private Storage				
Under 45	4	20¼-23¼	22½	43-51	48	94-110	101
45-49	4	22¾-24¼	23½	22-51	42	82-105	93
50-54	2	23¾-24	24	46-48	47	93- 99	96
55 or over	3	23¾-25	24½	35-59	43	70-123	90
Total	13	20¼-25	23½	22-59	45	70-123	95

Eastern Eggs

Eastern eggs predominated in the November market. Again tabular analysis seems to show the dominating influence of weight. There was but little variation in quality at different prices among the chain stores. However, the quality of the higher-priced private-store eastern eggs was much higher than for the lower-priced groups.

Western Eggs

The western eggs which were purchased at chain stores at the higher prices were slightly larger and of much better quality than those purchased at lower prices. Among private stores price was not a criterion of weight and quality above the lowest price group.

Group Averages

Tables 7 and 8 afford an opportunity to observe average price differentials between stores and egg grades relative to weight and quality. Average weight for the various classes is a constant in April. There is an average margin of 3 cents among private stores over chains. The buyer would be compensated for this charge by the extra service rendered by the private stores.

The 3-cent margin carries through for the other months, with the exception of eastern eggs in August when the margin is 6 cents and for western eggs in November when the differential is reversed. Weights, however, are variable and the higher differential is often for a lighter egg.

Table 7.—Weight Averages and Average Price Paid

	April		August		November	
	Weight	Price	Weight	Price	Weight	Price
Chain Eastern	24	49	24½	65	24	80
Private Eastern	24	52	24	71	23	83
Chain Western	24	38	22	46	24½	66
Private Western	24	41	23	49	23	63
Chain Storage	....	....	22	43	23	46
Private Storage	....	....	.....	....	23½	48

In quality, however, the private-store eggs were superior except in the case of western eggs in November. The superior quality of private-store eggs is especially noticeable in eastern eggs. A study of these averages also indicates very well the reason for the low price differential between western and eastern eggs in April and the wide differential in August and November. There is very little difference in quality between westerns and easterns in April, but there is considerable difference in August and November. It may be noted in passing that August cold storage eggs were superior in quality to westerns and were purchased at a lower price.

Table 8.—Quality Averages and Average Price Paid

	April			August			November		
	Air Space	Internal Score	Price	Air Space	Internal Score	Price	Air Space	Internal Score	Price
Chain Eastern	36	76	49	32½	75	65	41	88	80
Private Eastern	28	65	52	27	66	74	34	74	83
Chain Western	38	79	38	40	88	46	42	89	66
Private Western	36	75	41	37	85	49	47	99	63
Chain Storage	...		.	36	78	43	52	105	46
Private Storage	.	.		.... .	....	....	45	95	48

Branded Eggs[4]

If the above variations in quality appear in the ordinary dozen of eggs at retail stores, the question may be asked—"Can the consumer be sure of quality and value for his money by buying branded eggs?" A record of brands was taken for April and August only. Although 26 brands were purchased in the survey, only 5 brands in April and 4 in August occur frequently enough to be of significance. Table 9 gives the variations which were found in each of the internal and external quality factors. Internal quality varied from moderately fresh eggs to the poorest quality found in the survey. Internal quality was poorer in August than in April. The variation in weight per dozen was about the same for the two months. The range in weight of eggs within the dozen was about the same in both months.

TABLE 9.—QUALITY VARIATIONS IN BRANDED EGGS

Brand No.	Price (cents)	Air Space (score)	Whites (score)	Yolks (score)	Net Weight (ounces)	Range in Weight (ounces)	Dirties	Final Internal Score
				April				
1	31-35	36-49	14-26	18-26	21½-23½	12-26	1-10	68- 97
2	37-39	34-55	13-33	13-32	22½-26½	21-28	0- 6	60-120
3	39-41	31-54	16-30	17-26	21 -26½	18-29	0- 6	73-110
4	33-47	33-49	12-23	17-25	22 -25½	18-28	0- 5	66- 92
5	33-55	27-44	12-25	16-25	20½-26	20-28	0- 3	58- 89
				August				
1	41	32-51	23-31	20-29	20½-23½	17-28	1-11	51-110
2	51	32-48	20-29	18-27	22½-25½	18-28	0- 7	74-102
3	29-51	35-45	22-31	18-31	21½-24½	19-28	1- 9	79-106
4	63	30-54	19-30	16-29	23 -25	21-26	2- 8	67-113

To illustrate the variations within the brand, Tables 10 and 11 are shown. The conclusion is obvious that the branding of eggs does not constitute a guarantee of quality or of uniformity, nor is there any assurance that the brand is worth the price paid.

Grade Maintenance

Undoubtedly some of the difficulties found in branded eggs lie in the policy of the management in the houses back of the branded eggs. Their candlers may receive different instructions at different times. However, it is quite apparent that much is still to be done in the care of eggs in retail stores. The retailers have no uniform practice in regard to the care of eggs. There is also a great variation in the manner in which stores are equipped to carry eggs. There is little variation between equipment possessed by chain and private stores. About one-third of the stores have full refrigeration. About one-fourth have partial refrigeration and nearly two-fifths have no refrigeration. It was found in a survey carried on by the Bureau of Agricultural Economics[5] that eggs under ordinary circumstances were lowered one grade for the first three to five days under ordinary store conditions. In addition our survey tells us nothing of the care the eggs re-

[4]Only distributors' brands are used in the analysis. Producers' brands occurred too infrequently.

[5]Botsford, H. E. Some facts about eggs and the retailing of them. American Creamery and Poultry Produce Review, December 3, 1930, p. 201.

ceived by the managers. It will never be possible to guarantee quality to the consumer until there is some uniformity of care given to the preservation of eggs in local stores.

TABLE 10.—VARIATION IN QUALITY FOUND IN FOURTEEN DOZEN OF A POPULAR BRAND OF EGGS

BRAND NO. 2

Price per dozen (cents)	Air Space (score)	Whites (score)	Yolks (score)	Net Weight (ounces)	Range in Weight (ounces)	Dirties	Final Internal Score
				April			
37	43	23	24	26½	23-26	4	90
39	34	13	13	25½	23-28	2	60
39	40	18	25	25	24-28	6	83
39	47	18	14	24	22-26	3	79
39	34	19	17	22½	21-26	0	70
39	55	33	32	24	2 -28	1	120
				August			
51	40	21	20	23½	20-24	3	81
51	32	22	20	24	23-26	3	74
51	38	20	18	25½	23-28	1	76
51	46	26	24	23	18-26	0	96
51	37	28	27	22½	19-28	7	92
51	48	28	26	22½	22-23	4	102
51	38	26	27	23	21-27	3	91
51	47	29	25	23	21-24	5	101

TABLE 11.—VARIATION IN PRICE AND QUALITY FOUND IN ONE BRAND OF EGGS

BRAND NO. 5

Price per dozen (cents)	Air Space (score)	Whites (score)	Yolks (score)	Net Weight (ounces)	Range in Weight (ounces)	Dirties	Final Internal Score
				April			
33	35	16	16	24½	20-28	1	67
41	34	20	19	20½	20	0	73
46	44	19	23	24½	22-24	2	86
46	39	20	23	24	21-26	1	82
46	39	25	25	24½	21-26	2	89
46	40	23	22	24½	21-25	0	85
55	33	15	17	25	24-26	0	65
55	27	12	19	25½	23-28	1	58
55	33	16	17	26	24	3	66
55	28	18	18	26	23-26	0	64
55	30	21	20	25½	24-27	0	71

Summary of Tabular Analysis

The tabular analysis may be summarized as follows: The best and the poorest dozen of eggs were found in April. The poorest dozen, a well-known, labeled brand, was almost inedible and cost but 10 cents less than the very best dozen. The consumer who buys eggs in cartons has but little opportunity to know what she is buying. However, although the consumer does have to take a

chance, the survey would show that, on the average, weight varies with price through most of the price range. Quality, as reported by air cell, condition of yolk and condition of white, is a much more variable factor. Although quality was more variable than weight, the lowest price of eggs usually represented the lowest quality. Moderately high prices usually insured high quality, but high premiums paid did not guarantee highest quality. Many of the eggs for which the highest prices were paid were no better than those purchased in the moderately priced groups. The average quality of eastern eggs was invariably higher than the average quality of western eggs. Storage egg prices showed but little relationship to quality, but weight varied directly with price throughout the price range.

The margin between private-store and chain-store prices was 3 cents as an average in the three time periods. As the average quality was also better, the extra service rendered by the private store cost nothing.

Branded or labeled eggs should assure the consumer of some degree of uniformity of quality. The survey indicated that this was not true. There was a great range of quality and some range in weight in any one of the various brands purchased. Price was the only uniform factor.

It may be concluded from the survey that price is not a satisfactory criterion of egg quality in eggs purchased from retail stores. It is, however, the best measure the householder has when she buys eggs. Undoubtedly much of the variation in quality occurs after the eggs are in the hands of the retailer. All the work which has been done in egg grading will come to naught as long as retailers treat eggs as they would canned goods. Producers, consumers and dealers should be interested in the consumer getting what she pays for.

CORRELATION ANALYSIS

The tabular analysis was conducted in order that the average reader might understand the results of the study. However, in order to make a tabular analysis it was necessary to classify the data and conduct the analysis by means of averages. In such an analysis many characteristics of the data and relationships are covered up. A more scientific analysis may be made by the use of correlation methods.

Relation of External Quality to Price

External quality factors may be observed by the buyer. Hence it is often assumed that there should be some definite relationship between the appearance of a dozen of eggs and the price paid. The quality factors considered as external are: weight, number of dirties, uniformity of color and uniformity of size. Weight, as shown in the tabular analysis, has a dominating influence. The other factors proved to have some influence on price. Weight was taken from the other external factors and placed along with the internal factors for study.

The multiple correlation coefficients which were obtained show that there is some relationship between price and external quality factors (less weight) for August and April. In both months the relationship was significant in each of the sub-classifications except for eastern eggs in April. It appears that external factors exert very little influence on price of eggs sold in chain stores in August. In one case only, that of private-store eggs in August, do the external quality factors cause as much as 35 per cent of the price variations due to quality. In all of the remaining cases the influence is below 25 per cent. (See Table 12).

TABLE 12.—CORRELATION OF PRICE AND EXTERNAL QUALITY FACTORS MINUS WEIGHT

	Coefficient of Correlation	Regression Coefficients		
		Range in Weight	Variation in Color	Dirty Eggs
		April—N=217		
All Eggs	+.48155	-.0724	-.2391	-.3666
Chain Stores	+.4769	-.1767	-.1451	-.3910
Private Stores	+.4691	+.0168	-.2101	-.3556
Eastern Eggs	+.1772	-.0304	-.0838	-.1557
Western Eggs	+.4494	-.1481	-.1343	-.3681
		August—N=198		
All Eggs	+.47655	+.0050	-.2126	-.3607
Chain Stores	+.2592	-.0517	-.1018	-.2080
Private Stores	+.5951	+.1179	-.2593	-.4170
Eastern Eggs	+.4055	+.1672	-.2646	-.1926
Western Eggs	+.4352	+.0406	-.1129	-.3839
		November—N=84		
All Eggs	+.1682	+.0380	-.0756	-.1311
Chain Stores	+.2121	-.0363	-.2161	+.0049
Private Stores	+.2283	+.0919	+.0025	-.2202
Eastern Eggs	+.3438	+.2314	-.1549	-.1418
Western Eggs	+.3677	-.1244	+.1865	-.2552

The November measures are statistically nonsignificant, partially due to the small number of samples for that month. Because of the insignificance of the coefficients obtained for this month there will be no further discussion of the November measures in regard to external factors.

Range in Weight

Range in weight, as explained above, refers to the lack of uniformity of egg size within each dozen. The lack of significance in the regression coefficients leads to the conclusion that the variation in the size of eggs within each dozen has little or no effect on price.

Number of Eggs Off Color

The effect of off-color eggs on price was more important than weight variation. For each egg off color the reduction of price in April for all eggs was nearly .5 of a cent. In private stores this amount was .4 of a cent but only .25 of a cent for chain-store and western eggs.

In August the reduction in price for each egg of different color was nearly .5 of a cent. The reduction was highest in private stores and for eastern eggs. These losses were slightly over .5 of a cent in either case. Among chain-store and western eggs the loss was less than .25 of a cent for each off-color egg.

Dirty Eggs

The significance of dirty eggs as an influence on price was very similar to that of off-color eggs. The reduction in price for each dirty egg in April was from .45 to .50 of a cent except in the case of eastern eggs.

In August the reduction for each dirty egg was slightly higher except for eggs sold in chain stores and for eastern eggs. For the latter group the loss in price was about .25 of a cent for each dirty egg.

Net Effect of External Quality Factors on Price

In figuring the combined effect of external quality factors on the price of eggs, range in weight may be disregarded. Considering the other two factors, the influence was from zero, in the case of eggs which contained no off-color or dirty eggs, to 8.36 cents a dozen with six off-color and twelve dirty eggs. The price of eastern eggs in April appeared to be unaffected by these factors, but it is probable that such results were obtained because of the small percentage of eastern eggs which were dirty and a still smaller percentage of off-color eggs.

In August the maximum loss of all eggs could be but 6.8 cents as compared with 8.36 cents in April. For eastern eggs the maximum loss would be 5.49 cents, but in any case it is hardly conceivable that the conditions under which there would be a maximum loss in price would take place.

Internal Quality Factors

The combined effect of weight, together with the three factors of internal quality for all eggs purchased in all stores, was greater during the period of high prices and during the period of low demand and hot weather than in the spring of the year when quality was good and supply was well in excess of current demands. These factors had most effect on price during hot weather, the difference being 15 per cent more than during the period of low prices. As between stores the factors had relatively more effect on price in private stores than in chain stores during every period of the year. This was especially noticeable in April when the percentage was 20.5 per cent in favor of the private stores. Similarly quality and weight factors had more influence on the price of eastern eggs than western eggs at all seasons of the year. These relationships are also shown when each major grade group is broken down as between private and chain stores.

Table 13.—Corrected Correlation Coefficients Between Internal Quality Scores (including weight) and Price

	April	August	November
All Eggs	.656	.762	.705
All Eggs (omitting weight)	.519	.643	.....
Chain Stores	.517	.708	.629
Private Stores	.682	.770	.715
Eastern Eggs	.530	.663	.606
Western Eggs	.427	.582	.426

Importance of Air Space

Air space, representing the amount of shrinkage in the egg, is a direct function of the time and conditions under which eggs have been held. It affects flavor and interior quality and any relationship shown between air space and price should be of significance in the establishment of grades, since it is the one factor of internal quality that can be determined easily by the individual producer. In November, air space was the most important single factor affecting price in both types of stores. It stands second in importance to weight on the basis of major grade groups, eastern and western. It is the most important internal factor, being the only one having any marked relationship to price. In general, an increase of one point in the score on account of air space produced a drop of

slightly more than one cent in price. This may be interpreted to mean that for each ⅛ inch additional air space per egg, prices on the average drop one cent per dozen. If all twelve eggs in a dozen showed ¼ inch air space instead of ⅛ inch, prices in November would be more than 12 cents below the average. This varies somewhat between eastern and western eggs and between chain and private stores. In November the drop in price in chain stores for increasing air space was approximately 63.63 per cent higher than the drop in private stores.

In April, air space is relatively unimportant as compared with weight. The average for all stores shows a net drop of 3 cents per dozen for each unit increase in air space score, or ¼ of one cent decrease for each ⅛ inch increase in size of air space in each egg. Relatively, then, air space has about one-fourth as much significance during a period of low prices as during a period of high prices.

Table 14.—Regression Coefficients Between Internal Quality Scores (including weight) and Price

	April	August	November
Air Space			
All Eggs	−.265	−.517	−1.172
All Eggs (omitting weight)	−.446	−.798	.....
Chain Stores	−.222	−.303	−1.801
Private Stores	−.024	−.641	−1.101
Eastern Eggs	−.068	−.388	−.550
Western Eggs	−.021	−.298	−.532
Yolks			
All Eggs	−.479	+.192	+.027
All Eggs (omitting weight)	−.479	−.068	.....
Chain Stores	−.021	+.116	−.176
Private Stores	−.762	+.091	+.373
Eastern Eggs	−.852	−.105	+.643
Western Eggs	−.274	+.431	+.033
Whites			
All Eggs	+.205	−.326	+.049
All Eggs (omitting weight)	+.281	−.129	.....
Chain Stores	−.130	−.374	+.285
Private Stores	+.214	−.134	−.419
Eastern Eggs	+.356	−.141	−.408
Western Eggs	+.004	−.356	+.065
Weight			
All Eggs	+2.424	+4.461	+3.180
All Eggs (omitting weight)	.....	.....	.....
Chain Stores	+1.873	+4.278	+2.258
Private Stores	+2.819	+4.481	+3.592
Eastern Eggs	+2.444	+2.313	+3.015
Western Eggs	+1.461	+2.672	+2.522

During August, when quality is relatively poor, air space again assumes a prominent part in determining price, standing next to weight. For eastern eggs it is more significant than weight. Air space is relatively twice as important in determining price in private stores as in chain stores during August. In general the average for all stores shows a decrease in price of ½ of a cent for each egg

showing an air space ⅛ inch above the average, while private stores show a decrease in price of 3/5 of a cent for a similar increase in air space.

Condition of Yolk

Condition of yolk is relatively unimportant except during the spring of the year at which time it has more effect than air space in determination of price. It is particularly important in connection with eastern eggs and in private stores. During this period an increase of one point in the score on account of poor yolks is sufficient to reduce the price per dozen almost ½ of a cent. In private stores the effect is to reduce prices ¾ of a cent, while with eastern eggs the average is more than 4/5 of a cent reduction in price for each additional egg in a dozen with a poor yolk.

Condition of White

Condition of white also appears to be relatively unimportant in price determination at any of the three seasons studied. August is the only month in which any significant relationship appears. The average for all eggs in this month shows a net loss of .3 cents per dozen for each additional point on the score of the condition of white. This factor is more important for chain stores than for private stores and for western eggs than for eastern eggs, although the exact measure of this difference is indeterminate.

The apparent unimportance of the condition of white and yolk is accounted for in part by the interrelationship between size of air space and the other two internal factors. This is shown by the relatively high correlation between these factors at all seasons, but particularly in November and August.

Effect of Weight

Weight is one of the most important factors affecting price at all seasons of the year, but is most important both relatively and actually in August. In this month each additional ounce per dozen causes an increase of 4.5 cents per dozen in price. In April each additional ounce of weight produces an increase of 2.4 cents per dozen, while in November the increase is 3.2 cents per dozen. In April weight is relatively more important in connection with eastern eggs and eggs sold in private stores, and in November the same holds true. In August the effect of weight is slightly greater in private stores than in chain stores and for western eggs than for eastern eggs. The differences are not large enough to be significant in either case.

The effect of the several factors on the price of all eggs may be summarized as follows:

	CENTS PER DOZEN		
	April	August	November
Each ⅛ air space per egg	−3.0	−6.0	−12.0
Each yolk worse than average	−6.0	−2.3	0
Each white worse than average	−2.4	−3.6	0
Each additional ounce per dozen less than average	−2.4	−4.5	−3.2
The combined effect of these factors	−13.8	−16.4	−15.2

Assume that a farmer or a storekeeper stores eggs under improper conditions; that perhaps the purpose of storing is to secure a higher market price. What are the chances of a net gain in receipts for the eggs? The eggs when gathered weighed 24 ounces per dozen. During the whole period they lose, on an average,

1 ounce per dozen, air space increases ⅛ inch, and there is an average loss of one egg on whites and no loss on yolks. According to the table shown above, this deterioration would amount to 7.8 cents per dozen in April, 14.1 cents per dozen in August and 15.2 cents in November. The loss per case would be $2.34 in the spring, $4.23 in the summer and $4.56 in the fall. This represents the cost of tardy marketing or of storing eggs under improper conditions.

Conclusion

The most definite and significant relationship discovered from this analysis is that prices are directly related to weight under all conditions. That weight is a significant factor is not new, the trade has long recognized this fact. However, it has not been known that weight is more important at one season of year than another and that the premiums which are paid for weight are fairly definite. If premiums are known, it is possible to carry on further research in egg production to determine whether the production of large eggs is profitable.

Size of air space, condition of white, and condition of yolk are largely determined by the delay in marketing and the conditions under which the eggs are stored from the time they are produced until they reach the consumer. Until further research is carried on as to the effect of time and various conditions of temperature and handling on the quality of eggs, all unnecessary delays must be prevented and temperature kept low if the eggs are to reach the market in proper condition.

Publication of this Document Approved by Commission on Administration and Finance
4M-6-32 No. 5671

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 283 May, 1932

Downy Mildew of Cucumbers

By William L. Doran

Downy mildew is a common and important disease of cucumbers in Massachusetts as well as in most of the eastern and southern states. This is a report on investigations of the source of the primary infection, the effect of climatic factors on the disease and on the fungus which causes it, and the prevention of infection by the use of fungicides.

MASSACHUSETTS STATE COLLEGE
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DOWNY MILDEW OF CUCUMBERS

By William L. Doran, Research Professor of Botany

INTRODUCTION

Downy mildew, caused by the fungus *Peronoplasmopara cubensis* (B. & C.) Clint., is one of the most common and important diseases of field-grown cucumbers in Massachusetts. It was present here in seven out of the past eight years. In greenhouses, too, its onset is so sudden and its spread so rapid that it is regarded by growers with much concern.

The disease is by no means new, for it was present in Massachusetts as early as 1890 (21).[1] Its distribution has recently been discussed by Weber (48), and, as he points out, it has been found at some time in all regions of the United States except the more arid parts. Because of its economic importance and general distribution, this disease and the fungus which causes it have received considerable attention from earlier investigators. There is, nevertheless, much about the fungus and the disease which remains obscure.

Work described in the present paper was undertaken with the object of adding to the knowledge of host relationships, source of the primary infection, effect of climatic factors on sporulation and on spore germination and infection, and prevention of infection as by the use of fungicides.

HOST RELATIONSHIPS

Relative Susceptibility of the Species of Cucurbits

Peronoplasmopara cubensis has been reported (39, 40, 48) as occurring on 28 species of plants, all in the family Cucurbitaceae. These include cucumber, muskmelon, watermelon, squashes, pumpkin, and several gourds, ornamentals, and species not cultivated.

The species named in Table 1 were grown in the field with rows of cucumber plants alternating with rows of the other species. All plants were inoculated three times by the application of a water-suspension of the conidia of *P. cubensis* obtained from the leaves of cucumber. As was evidenced by the severity of downy mildew on cucumber, the season was very favorable to the disease, and the relative susceptibility of the several species was put to a fair test. The degrees of infection which resulted on each species in the course of the growing season are recorded in Table 1.

Downy mildew was severe on cucumber, moderate on muskmelon, present as only a trace on watermelon, and absent from squash and pumpkin. There was no infection or only a trace of infection on the other species tested.

In other fields and in several years, downy mildew has been observed causing the death of cucumber leaves when it was absent from or present as no more than a trace in adjoining plots of watermelon, summer squash, Hubbard squash, and pumpkin.

The only species of the Cucurbitaceae which grow without cultivation here are *Sicyos angulatus* and *Echinocystis lobata*. The former is rare and the latter is common. But downy mildew has not been found here on *E. lobata*, even when growing near infected cucumbers. These observations and those recorded in Table 1, like those of Clinton (10) and Halsted (18) support the conclusion of

[1]Reference is made by number to "Literature cited," p. 20.

TABLE 1.—RELATIVE SUSCEPTIBILITY OF SEVERAL SPECIES OF CUCURBITS TO INFECTION BY *P. cubensis* FROM CUCUMBER

Species inoculated		Degree of infection
Cucumis sativus L.	Cucumber	Very severe
Cucumis sativus L. var. *anglicus* Bailey	English forcing cucumber	Very severe
Cucumis Melo L.	Muskmelon	Moderate
Cucumis Melo L. var. *inodorus* Naud.	Cassaba melon	Moderate
Cucumis Anguria L.	Bur gherkin	None
Cucurbita Pepo L.	Field pumpkin	None
Cucurbita Pepo L. var. *condensa* Bailey	Summer squash	None
Cucurbita moschata Duchesne	Cushaw squash	None
Cucurbita maxima Duchesne	Hubbard squash	None
Citrullus vulgaris Schrad.	Watermelon	Trace
Sicyos angulatus L.	One-seeded bur cucumber	Trace
Echinocystis lobata Torr. & Gr.	Wild balsam-apple	None
Luffa cylindrica Roem.	Rag gourd	Trace
Benincasa hispida Cogn.	White gourd	Trace
Lagenaria leucantha Rusby	White-flowered gourd	Trace
Trichosanthes Anguina L.	Serpent gourd	Trace
Momordica Balsamina L.	Balsam-apple	None
Melothria scabra Naud.		None
Bryonopsis laciniosa Naud. var. *erythrocarpa* Naud.		Moderate

Wilson (52) that the native species of the Cucurbitaceae are comparatively immune to downy mildew.

It seems safe to conclude that cucumbers are not in danger of infection by *P. cubensis* from wild plants in Massachusetts, and that *P. cubensis* from cucumber does not infect or does not readily infect certain other cultivated species (watermelon, pumpkin, squashes, and certain gourds) which have been reported as hosts. There is, of course, a possibility of biologic specialization by this fungus.

Factors Affecting Susceptibility of Cucumbers

Varietal Differences

Twenty-eight varieties of cucumber, including those common in the field and in greenhouses, have been grown, and downy mildew resulting from natural infection has been equally severe on all of them. The results of these observations agree with those of Clayton (9) and Weber (loc. cit.), neither of whom found any differences in the susceptibility of the varieties of cucumber to downy mildew.

Age of Leaves

The oldest cucumber leaves are usually the first to be attacked by downy mildew in nature. The disease is almost never found on young leaves of cucumber and, as was observed by Halsted (17), this is true also of squash. To determine the relation of age of cucumber leaves to their susceptibility to infection by *P. cubensis*, leaves of various ages were inoculated by placing them on drops of a water-suspension of conidia. These leaves were grouped into eight classes on the basis of age. There was no infection of the three youngest leaves of any plant, and there was but little infection of the fourth leaves. Older leaves were all and equally susceptible. In these and other experiments, the youngest leaves of cucumber were entirely resistant to infection by *P. cubensis*.

According to Clinton (loc. cit.) infection may take place either through the stomata or directly through the epidermis. Stewart (42) and Selby (38), however, observed infection by the germ tubes of the zoospores of this fungus only

through the stomata, and this is the only method of infection seen by the writer. Using the xylol test of Molisch (31), it appears that the stomata of the youngest leaves of cucumbers are not open. This fact, and the relative difficulty with which such leaves are wetted, is believed to explain the resistance of young cucumber leaves.

Fertilizers

It has been reported (28) that applications of potassic fertilizers decrease the susceptibility of some plants to certain fungous diseases. Blattny (5) observed indications of this effect of potash, and of lime, on downy mildew of hop; and, according to Quanjer (35), downy mildews of cabbage, grape, and lettuce may be more severe in soils deficient in potassium.

In order to learn whether or not potash and lime have any effect on the susceptibility of cucumbers to downy mildew, cucumber plants were grown from seeds to the fruiting stage, in soil (an infertile and fairly acid sandy loam) treated as indicated in Table 2. The plants were grown in two-gallon crocks with treatments in triplicate. All plants were inoculated with *P. cubensis*, and the percentages of leaves which became infected within five weeks after inoculation are recorded in Table 2. The susceptibility of cucumber to downy mildew was not affected significantly by potash or lime (or a complete fertilizer) as applied to this soil.

TABLE 2.—EFFECTS OF POTASH AND LIME ON SUSCEPTIBILITY OF CUCUMBER TO DOWNY MILDEW

Soil treatment (per acre)	Percentages of leaves infected
Check (no lime, potash, or fertilizer)	50
Potassium carbonate, 600 lbs.	46
Potassium carbonate, 1200 lbs.	67
Hydrated lime, 3 tons	52
Hydrated lime, 4 tons	61
Hydrated lime, 3 tons and potassium carbonate, 600 lbs.	52
Hydrated lime, 4 tons and potassium carbonate, 1200 lbs.	45
Complete fertilizer (5-8-7), 1500 lbs.	42
Complete fertilizer, 1500 lbs. and hydrated lime, 3 tons	45
Complete fertilizer, 1500 lbs. and hydrated lime, 4 tons	40
Complete fertilizer, 1500 lbs. and potassium carbonate, 600 lbs.	41
Complete fertilizer, 1500 lbs. and potassium carbonate, 1200 lbs.	59
Complete fertilizer, 1500 lbs., hydrated lime, 3 tons, and potassium carbonate, 600 lbs.	49

SOURCES OF THE PRIMARY INFECTION

Search for Oospores and Other Wintering-over Stages of the Fungus in the Field

Many species of the Peronosporaceae live through the winter by means of oospores, and a number of investigators (13, 17, 21, 11, 36, 10, 4, 14) have, therefore, looked for oospores of *P. cubensis*. Rostowzew (36) is, however, the only one who believed that he found them. But he did not establish, as by their germination and infection of cucumber with them, that they were indeed oospores of this fungus.

The writer has repeatedly looked for oospores in cucumber leaves infected with or killed by *P. cubensis*. This has been done in the fall, before and after the death of the leaves, and also in the following spring and summer, after the dead diseased leaves had passed through the winter (or through two winters) buried in soil (outdoors, in a greenhouse, or in a laboratory). Oospores of one

of the Phycomycetes have occasionally, although rarely, been found by the writer in the remains of cucumber leaves, especially petioles which, after having been killed by downy mildew, had passed through one winter in the soil in the field. Efforts to germinate them or to infect cucumbers with them have, however, been unsuccessful. Thus no proof was obtained that they are oospores of *P. cubensis* or that this fungus produces oospores.

Clinton (loc. cit.) suggested the possibility that the oospores of this fungus, if there be any, may develop only after the union of distinct and sexually different mycelial strains. With this possibility in mind, the writer has inoculated the same leaves of cucumber plants with conidia of *P. cubensis* obtained from several sources. After leaves so inoculated had become infected and killed by downy mildew, they too were buried in soil over winter. The decomposed residue of such leaves was examined for oospores one and two years later, but none were found.

It is conceivably possible that this fungus might live through the winter in the soil in some other stage than as oospores, e.g., as saprophytic mycelium or specialized and long-lived conidia. None have been found, however, and no infection resulted when Clinton (loc. cit.) and Adams (2) inoculated cucurbits with soil in which cucurbits had died of downy mildew the previous season or with the remains of the leaves of cucurbits which had been killed by downy mildew.

On numerous occasions in the course of this investigation, cucumbers have been inoculated with soil in which cucumbers had grown and died of downy mildew one and two years before, or with inoculum consisting of cucumber leaves killed by downy mildew the previous fall and wintered-over in the soil outdoors. In very few cases has infection followed, and these few were always at a time of year when the conidial stage was present in the field here. It is, therefore, at least possible that such little infection as did occur was accidental rather than from inoculation with over-wintered material, and the only safe conclusion is that the results of such inoculations were negative. Thus, as in the work of other investigators mentioned above, no evidence was secured that downy mildew is associated with the over-wintering of *P. cubensis* in dead host plants here.

As supporting evidence, it should be added that there is no apparent relation between previous cropping systems and the time of appearance or severity of cucumber downy mildew. The disease often reappears in fields where it has occurred before, but the writer, like Stewart (loc. cit.), has often found it in fields in which no cucurbits had been grown for several or many years before. Adams (1) did not find any evidence that the previous crop had any relation to the prevalence of the disease; and in Florida, too, Weber (loc. cit.) has noted that crop rotation does not protect cucumbers against downy mildew.

It has been observed that the disease when it appears at all in Massachusetts, and it usually does, is to be found in every or almost every field of cucumbers, and at approximately the same time, whether or not cucumbers were previously grown in these fields. It seems evident, therefore, that the source of the inoculum may be distant and that the inoculum is probably air-borne.

In this connection, it should be noted that Adams (1) found no evidence that *P. cubensis* is seed-borne. The fungus has not been found in or on the fruit of the cucumber, and inoculations of cucumber fruits by the writer have never resulted in infection.

Relation of the Disease in Greenhouses to the Disease in the Field

A fall crop of cucumbers is often started in greenhouses in Massachusetts while field-grown cucumbers infected with downy mildew are still living. Under these conditions, greenhouse cucumbers frequently become infected by *P. cubensis* in the fall. The observations here recorded lead to the conclusion that such infection comes from the field rather than from the previous greenhouse crop of cucumbers. Downy mildew is not uncommon in the fall in greenhouses in which the soil has been disinfected by steaming and the air by sulfur fumigation since the last crop of cucumbers was removed. The conclusion that the fungus enters greenhouses in the fall from field-grown plants is further supported by the observation, first recorded by Stone and Smith (45), that greenhouse cucumbers started in August and September are more likely to become infected with downy mildew than are greenhouse cucumbers started later, that is, in the fall after most or all field-grown cucumbers have been killed by frost. It should also be noted that in every year from 1925 to 1930, the disease was present in Massachusetts in fields each summer and in greenhouses each fall; but there was no downy mildew in the fields here in 1931 and the disease did not appear in greenhouses here the following fall and winter.

It has been suggested (52) that *P. cubensis* lives through the winter on greenhouse cucumbers and from them is disseminated to field-grown cucumbers the next spring and summer. Observations in numerous greenhouses and in each of the past seven years lead to the conclusion that this does not often occur in Massachusetts, however. Downy mildew has usually been found here on greenhouse cucumbers in the fall, but not in the winter later than January. The observations of Stone and Monahan (44) were similar. They often found downy mildew on greenhouse cucumbers in the fall, but for seven consecutive years they learned of no case in which it was present all winter in a Massachusetts greenhouse, and in only one year did Stone (43) find the disease in greenhouses here earlier in the summer than it appeared in the field. Guba[2] too, although he has made frequent observations over a period of seven years, has not seen downy mildew on greenhouse cucumbers in Massachusetts earlier in the year than September, which is of course no earlier, in fact usually a little later, than it was also present in the field. It should be noted, however, that in one year, 1915, Osmun (33) found the disease in greenhouses in Massachusetts in May, but this was regarded as very exceptional.

The usual absence of downy mildew from greenhouse cucumbers in Massachusetts in winter and spring is explainable by the fact that in very few greenhouses in this State is that crop grown uninterruptedly throughout the winter, and by the fact that the drying effect of the heating pipes in winter is ordinarily such as to lower the humidity of the air below that necessary for the fungus. The writer has kept *P. cubensis* alive and growing on greenhouse cucumbers for 23 consecutive months, but to do this all winter it was necessary to inoculate plants at frequent intervals and to increase and maintain the humidity of the air above that which is common in winter in ordinary greenhouse practice. Whitcomb and Guba (51) have described the prevention of powdery mildew of cucumber by greenhouse management, that is, by keeping down the relative humidity of the greenhouse air. This method is no less effective against downy mildew, and the disease is a menace in greenhouses only in the fall before much artificial heat is used.

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[2]Letter of January 29, 1931 from E. F. Guba of Mass. Agr. Expt. Sta.

Wintering-over of the Fungus in the South and Dissemination Northward by Winds

Peronoplasmopara cubensis is known to live through the winter in Florida. Hume (20) stated that it may be found there on living hosts throughout the year, and Weber[3] has recently informed the writer that cucurbits are grown and *P. cubensis* has been found on them in every month of the year in that State.

It has been suggested or accepted by several investigators (10, 32, 43, 14) that *P. cubensis*, living through the winter in the South, may be disseminated northward in the spring and summer with the northward advance of the season and the cultivation of the host plants.

Lacking oospores or other equally long-lived spores, the dissemination of this fungus, either locally or for greater distances, can at present be attributed only to conidia. The conidia of the downy mildew fungi are usually thought of as being very short-lived, but Angell and Hill (3) have found that the conidia of some of the downy mildew fungi (*Bremia lactucae* Regel, *Peronospora parasitica* (Pers.) de Bary, and *Peronospora hyoscyami* de Bary) may retain their viability for several days or even weeks. Similarly, Katterfield (23) found that conidia of *Peronospora schleideni* Ung. may remain viable in moist air for ten days.

The writer has succeeded in keeping the conidia of *P. cubensis* alive in moist air for 50 hours, but not longer. Spores which can live that length of time may, however, be carried long distances by the wind.

Ascending air currents may carry fungous spores, like dust, high into the air. Spores have been found floating in the air at altitudes up to 11,000 feet (41). Such spores, even at much lower altitudes may be carried horizontally many miles by wind before they settle to earth. Thus Pennington (34) found evidence that wind-borne aeciospores (of *Cronartium ribicola* Fisch.) were carried to a point 110 miles from their starting place. According to Lambert (26), there is enough movement of southerly winds to carry urediniospores of *Puccinia graminis* Pers. from Texas to the spring wheat area in the North in less than three days, and the observations of Wallace (47) lead him to the conclusion that these spores, borne north by the wind from Texas or even Mexico, may be inoculum for wheat in the Northern States.

The conidia of the downy mildew fungi are no less well adapted to distribution by wind both because of their smallness and the great numbers in which they are produced. Weston (49) observed that the spread of the Philippine Sclerosporas of maize followed closely the direction and extent of the nightly air currents. He did not attempt to determine the precise amount or extent to which the conidia of these fungi were disseminated by winds, but he found that they were carried for at least several miles and concluded that wind is the most important factor in their dissemination. Leach (27), similarly, concluded that infection of beets by *Peronospora schactii* Fckl. can often be accounted for only by wind-borne conidia.

As Lambert (loc. cit.) has pointed out, dust storm analogies and other evidence indicate that the wind is capable of carrying fungous spores many miles, or as far as from Florida to Massachusetts. But it is not necessary to postulate the flight of the conidia of *P. cubensis* the whole length of the Atlantic seaboard. Downy mildew of cucurbits is present most years, as the season advances, in most or all of the Coastal States, and it is entirely possible for the conidia to be borne from Florida to Georgia to the Carolinas and so on northward by several

[3]Letter of October 16, 1931 from G. F. Weber of Fla. Agr. Expt. Sta.

stages as the host plants are grown farther north; the absence of the disease in the North when it is already present in the South being due as much to the absence of the host as to the absence of inoculum. The evidence being, in the nature of the case, necessarily largely circumstantial, it is easier to prove that the inoculum can be carried northward by winds than that it is so carried. It is the belief of the writer, however, on the basis of the earlier discussion and the evidence presented below, that the conidia of *P. cubensis*, the primary inoculum, reach Massachusetts from Connecticut, Long Island, and the lower Hudson Valley after the fungus has reached these regions by the aid of wind from more southerly points. Because of downward air currents and rain, it seems unlikely, though possible, that the spores move the whole or nearly the whole length of the Atlantic Coast of the United States on any one wind or in any one flght. Even so, the total distance could be covered in a relatively short time, and with only short interruptions, for, as is discussed below, infection by, and incubation period and sporulation of *P. cubensis* may all occur in a few days.

In each of the seven years from 1924 to 1930 inclusive, downy mildew of cucumber has been found in the field in Massachusetts, and has always appeared within the first 18 days of August, whether the summer was rainy or dry. But the disease was not found in this State in 1931 although many cucumber fields were examined at weekly intervals, or oftener, up to the time of killing frosts. The weather of the season was not significantly different from that of previous seasons in which downy mildew had been severe, and the absence of the disease in 1931 is attributable only to lack of primary infection rather than to failure of the disease to spread within a field.

In 1931, downy mildew of cucurbits seems to have been decidedly less common and less severe south of here also.[4] In Connecticut, the disease was not found until the very end of the season and then only in one field, although the weather of the season was, in the opinion of Clinton, not unfavorable to it and it was present as usual the previous year. It was not reported as present in either New York or Pennsylvania. Only a trace of infection was found in Delaware. It was present in West Virginia, but to a lesser extent than the previous year. It was either absent or very unimportant in South Carolina. There was very little of the disease in Georgia, although the weather (rainfall) was considered favorable to it in June and July. In Florida, and this is of particular interest, fields were remarkably free from downy mildew, and the disease was not of economic importance.

There was, therefore, a minimum chance of the causal fungus reaching Massachusetts from states farther south and under these conditions, downy mildew of cucurbits did not appear in this State.

Most of the primary infection in Massachusetts occurs in August. It is at least interesting to note that in August, 1931, there were 30 per cent fewer days with southerly winds and about 39 per cent less total southerly wind movement in miles here than the averages of the preceding five years.[5] With very little inoculum in states to the south in 1931 and with much less southerly wind movement here than usual, the fungus did not appear in Massachusetts that year.

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[4] The statements in this paragraph are based on information received from G. P. Clinton, C. Chupp, G. L. Zundel, J. F. Adams, C. R. Orton, G. M. Armstrong, F. Van Haltern, and G. F. Weber, representing respectively the Agricultural Experiment Stations of Connecticut, New York, Pennsylvania, Delaware, West Virginia, South Carolina, Georgia, and Florida.

[5] This information was furnished by C. I. Gunness, Meteorologist of Mass. Agr. Expt. Sta. in letter of March 8, 1932.

INFECTION AND SPORULATION AND THEIR RELATION TO ENVIRONMENT

A plant disease such as downy mildew of cucumber appears and spreads only when the inoculum, in this case conidia, comes in contact with susceptible host plants under conditions, as of temperature, humidity, and absence of fungicide, which are favorable to spore germination, infection, and sporulation. Spore germination, which necessarily precedes infection, will be first considered.

Germination of the Conidia

All germination of the conidia of this fungus observed in this investigation was by zoospores, the method of germination which has been seen and described by others (21, 38, 10, 25). Rostowzew (loc. cit.) described the germination of these conidia by germ tubes, but none were seen by the writer.

Conidia germinated freely in water, including dew and water of guttation, but not in merely moist air. Unsuccessful attempts were made to germinate conidia in the diluted juices of crushed leaves of cucumber. Conidia have been seen to germinate at temperatures between 8° and 29° C., with the best germination at 16° to 19° C.

According to both Kurosawa (25) and Hiura (19), the maximum temperature for their germination is 30° C. The optimum temperature for their germination as determined by Kurosawa was 20° to 22°C., but Hiura placed it somewhat lower, at 15° to 19° C. Kurosawa concluded that the minimum temperature for their germination was 9° C., but Hiura observed some germination at 4° C. Accepting even the more narrow limits (9° to 30° C. or about 46° to 86° F.), it is evident that there is very rarely a night or early morning here in August or the first part of September (when most of the conidial germination occurs) which is too warm or too cool for some germination of these spores.

The length of time required for the germination of conidia is of interest, for the shorter this time, the less are the conidia at the mercy of a changing environment and the greater is the chance for infection. In the investigations of Clinton (loc. cit.), the conidia germinated within two to four hours after being placed in water, and as observed by Kurosawa (loc. cit.), most of the conidia germinated within one to one and one-half hours.

It was found by the writer that the time required for their germination is affected somewhat by temperature. At temperatures between 8° and 24° C., all germination was completed within three hours, but conidia germinated within two hours and thirty minutes at 12° C. and within one hour and forty minutes at 18° C.

It is concluded that two to three hours on a leaf wet with rain or dew is enough for the germination of most of the conidia of this fungus, although even conidia from the same source, and not visibly different, do not all germinate at the same time.

Conidia in the preliminary stages of germination in water were much more readily killed by subsequent exposure to dry air than were conidia which had not been previously wetted. Cucumber leaves bearing conidiophores and conidia were wetted and kept wet for fifty minutes, at the end of which time they were quickly dried for twenty minutes. Conidia thus treated were killed, while conidia which had not been previously wetted were uninjured by this short exposure to dry air (at the same temperature, 20° C.). In this way, some conidia may be killed in nature if they are on a leaf which remains wet for a short time, but not long enough to permit germination to be completed.

Zoospores emitted from germinating conidia are, as has been described by Kurosawa (loc. cit.), usually active for about one hour, following which they remain motionless for about one hour before germinating. Conidia may, therefore, under favorable conditions, emit zoospores which later initiate infection by germ tubes all within four to five hours after the conidia have reached a leaf which remains moist during that period. As is discussed below in connection with infection, it was found that there is some infection even of leaves which remain wet no longer than five hours.

The length of life of conidia was found to depend on the moisture conditions which follow sporulation. The younger the conidia, the more freely they germinated. Conidia removed from cucumber leaves and placed (on glass) in moist air at 20° to 25° C. remained viable for 50 hours, but not half so large a percentage of them germinated at the end as at the beginning of that period. In drier air, the life of the conidia was relatively short. Conidia were removed, at hourly intervals beginning at 6 a. m., from cucumber leaves wet with dew on which the fungus had sporulated in the night. Conidia removed before 10 to 11 a. m. germinated freely, but there was no germination of conidia removed later in the day after the dew had dried from the leaves in the sunlight. Similarly, germinating conidia and motile zoospores were usually found on leaves wet with dew up to about 10 a. m., but not later.

Infection of Cucumber Leaves

Inoculum used in infection experiments was usually obtained by placing in water for two to three hours leaves on which the fungus had recently sporulated, for at the end of that time the conidia had germinated and zoospores were abundantly present in the water. Of course this method of obtaining inoculum was not used when the time necessary for infection was being investigated, since infection involves and must be preceded by germination of conidia. The high relative humidity necessary in order that inoculated plants may remain wet until infection has occurred was obtained by means of Wardian cases, or by covering plants with cloths supported on frames and kept wet with running water, or by increasing the humidity of one whole compartment of a greenhouse, which was easily possible at night and on cloudy days.

Cucumber plants growing in soil in two-gallon crocks, or shoots of plants rooted and growing in Knop's solution, were sometimes found convenient for inoculation purposes. In some cases detached cucumber leaves floated on sterile water were inoculated, but this method was not very successful. Cotyledons of cucumber seedlings were found to be easily infected on the living plants. In other cases, detached cotyledons, after being washed in sterile water, were placed in sterile Petri dishes with distilled water or a five per cent solution of glucose. These detached cotyledons were usable in inoculation experiments, for they remained alive two weeks in the sucrose solution and about three weeks in distilled water.

In order to determine how long leaves must remain wet in order to permit infection, cucumber plants were inoculated by placing on each plant 100 drops of a freshly made water-suspension of the conidia of *P. cubensis*. These plants were then placed in moisture-saturated air (at 18° C.), and after the intervals of time indicated in Table 3, some of the plants were removed to dry air for 12 hours, at the end of which time, they were returned to moisture-saturated air. The percentages of infection points which resulted, as compared with the 100 points inoculated on each plant (means for triplicates) are recorded in Table 3.

TABLE 3.—RELATION OF INFECTION OF CUCUMBERS TO LENGTH OF TIME INOCULATED PLANTS REMAIN WET.

Number of hours inoculated plants remained wet	Percentage of points inoculated at which infection occurred
24	76
14	71
12	77
10	82
7	47
6	22
5	5
2½	0

There was no infection of plants which remained wet only two and one-half hours after inoculation. Five hours on a wet leaf was enough to permit some infection, certainly enough to establish the fungus in a greenhouse or field. There was, however, much more infection of plants which remained wet six hours, and the maximum infection occurred on plants which remained wet ten hours after inoculation.

Cucumber plants which had been inoculated with a water-suspension of the conidia of *P. cubensis* were placed in moisture-saturated air at the time of inoculation. After 50 minutes, half of the plants were removed to dry air so that the foliage was entirely dry within 20 minutes. Thirty minutes later, they were returned to moisture-saturated air, with plants similarly inoculated, but not dried, and there all remained for 24 hours. No infection resulted in the case of plants which had been exposed to dry air for 30 to 50 minutes. This supports observations made in connection with the germination of conidia, to the effect that conidia which have been in water for a time may be very quickly killed by dry air, much more quickly than are conidia which have not begun to germinate.

In another series, cucumber plants were inoculated with conidia obtained early in the morning and at intervals of one hour from plants wet with dew in the field. Infection resulted up to the time that the sun dried the dew from the leaves from which conidia were obtained, but not later. It appears from this that infection in nature, in sunny weather and the absence of rain, takes place the same night or the same morning as that in which sporulation has brought the infecting conidia into existence. The same dew or rain (or water of guttation) which induces sporulation may also provide the necessary moisture for germination and infection. This is one reason why downy mildew often spreads so rapidly in the field.

Rain is unnecessary for infection by *P. cubensis*. Dew or water of guttation often provides all the moisture on the leaf which is necessary for infection. As has been noted by Clayton (9) and others, downy mildew of cucumber may be severe even in dry seasons.

When soil and air are sufficiently moist, as they sometimes are in greenhouses in the fall before artificial heating is used, water of guttation escapes from and collects on the margins of the leaves of cucumbers. An examination of cucumber leaves naturally infected in a greenhouse showed that more than half of the first infection occurred on the margins of the leaves. In order to investigate the part which water of guttation may play in infection, cucumber plants were inoculated by placing dry conidia on the dry leaves. Plants thus inoculated were grown in soil maintained at 70 to 75 per cent of its water-holding capacity

and in air with a relative humidity of not less than 90 per cent at about 20° C. Under these conditions, drops of water of guttation soon appeared on the margins of the leaves. A good infection, including sporulation, resulted, and it was confined to the margins of the leaves where the water of guttation had stood, although conidia had been applied all over the surface of the leaves. No infection resulted when cucumber plants were thus inoculated by placing dry conidia on dry leaves if the inoculated plants were then grown in soil and air too dry for water of guttation to appear.

The relation of air temperature to infection of cucumber by *P. cubensis* has been investigated by Hiura (loc. cit.) who concluded that the minimum temperature for infection is 10° to 15° C., the optimum about 20° C., and the maximum at or not far above 30° C. The writer has secured infection of cucumber plants inoculated at 10°C., but not below, and at 28° C., but not above; most complete infection has been secured at temperatures between 16° and 22° C. These temperatures at which infection is possible correspond fairly closely to the cardinal temperatures for the germination of conidia, to which reference has already been made.

Infection through upper as compared with lower surfaces of the leaves is of interest, as having a possible bearing on the use of fungicides. The observations of the writer lead him to agree with earlier investigators (38, 42) that infection by the germ tubes of the zoospores of this fungus is through the stomata. However, as has been recorded by others (38, 16), cucumber plants may be infected by this fungus through both the upper and lower leaf surfaces. As determined by the writer, there are two to three times as many stomata per unit area on the lower surface as on the upper surface of cucumber leaves, but there is abundant opportunity for infection through both surfaces except as they are protected by fungicides. In fact, it is probable that more leaves are infected through the upper surface, for the writer was able to prevent most (but not all) accidental infection by applying a fungicide to the upper surfaces of leaves, but not the lower.

The incubation period for downy mildew of cucumber may mean either the interval of time between inoculation and sporulation, that is, the appearance of conidiophores and conidia on inoculated leaves, or it may mean the interval of time between inoculation and the appearance of the yellowish leaf spots indicative of infection. These leaf spots usually appear three to five days after inoculation. With temperature and moisture conditions near the optimum, infection of leaves usually ends in sporulation within six to nine days after inoculation. In the case of cotyledons of cucumber seedlings, the incubation period may be shorter, so that conidiophores and conidia are produced four to six days after inoculation. If the incubation period is understood to end only with sporulation, it may, as is described below, be prolonged in dry air almost indefinitely, within the life of the plant of course. Even in moist air, the incubation period is affected somewhat by temperature. The incubation period ended in sporulation seven days after inoculation at 20° to 28° C. and nine days after inoculation at 16° to 20° C.

These results may help to explain the observation of Hiura (loc. cit.) who noted that the appearance of the disease in the field was hastened by high temperatures up to 30° C., and delayed by low temperatures near the minimum for infection.

Sporulation

Conidiophores and conidia of this fungus were found growing only on the true under side of leaves. This was the case even when leaves of cucumber were inoculated only on the upper surface, or when infected leaves were kept wet only on the upper surface, or when petioles of inoculated leaves were so twisted as to hold the leaves inverted. According to Rostowzew (loc. cit.), however, *P. cubensis* may sporulate, although rarely, on the upper surface of leaves. In the course of this investigation, cotyledons of cucumber seedlings were often inoculated and on them the fungus sporulated on both upper and lower surfaces, although the cotyledons, like leaves, have typical palisade cells above with spongy mesophyll below. In this, the behavior of the fungus is like that of *Peronospora schactii*, for Leach (loc. cit.) observed that the latter produced conidiophores only on the lower surface of the leaves of beets, but on both the upper and lower surfaces of cotyledons.

Good and equally complete sporulation was obtained at air temperatures between 16° and 22° C. The cardinal temperatures for the production of the conidia of this fungus as determined by Hiura (loc. cit.) are: maximum, 27° C.; optimum, 15° to 19° C.; and minimum, below 10° C. This is the same as his optimum temperature for the germination of conidia, but his maximum for sporulation is a little lower than for germination. In either case the range is great enough so that there is little likelihood of the disease being much checked by temperature in the field here.

Sporulation, as observed in the field, occurred most freely in the early morning on leaves then wet with dew. Rain is not necessary for sporulation. The moisture of dew permits and induces sporulation, germination, and infection, all within a few hours, ending with the drying of the dew by the sun in the course of the forenoon. In this, *P. cubensis* resembles *Sclerospora graminicola* (Sacc.) Schroet., for Weston (50) found that dew provides enough moisture for the production of conidia by that fungus. Van Everdingen (46) has similarly emphasized the importance of dew in favoring outbreaks of potato late blight.

As has been mentioned in connection with the incubation period, *P. cubensis* may live in inoculated leaves in dry air for several days or weeks without sporulating. Leaf spots appear, often rectangular and at first limited by small veins, but the violet or purplish-gray mats of conidiophores and conidia do not develop on them nor do the spots increase in size until the relative humidity of the air is raised almost to saturation. In long-continued dry weather, the tissue in these leaf spots and the fungus with them may die without the whole leaf being killed.[6] However, if the air becomes sufficiently moist before this occurs, sporulation follows very promptly. Cucumber plants inoculated with *P. cubensis* were allowed to remain in moist chambers, at 20° C., for two days following inoculation, at the end of which time they were placed in the dry air of a laboratory where they remained for three weeks. Leaf spots indicative of infection appeared on them six days after inoculation, but no conidiophores were produced in the course of three weeks in the dry air. At the end of this time, the foliage was wetted, the plants were placed in the moisture-saturated air of Wardian cases, and an abundant growth of conidiophores resulted within twelve hours.

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[6]It is not unlikely that the drouth of 1930 was in this way the cause of the limited inoculum in the South the following year, to which reference has already been made.

EFFECTS OF FUNGICIDES ON SPORULATION, GERMINATION, AND INFECTION, AND ON CUCUMBER PLANTS

Effects of Sulfur and of Copper-lime Dust on Sporulation

The effectiveness of fungicides against the downy mildews and many other fungi is usually explainable by the fact that they are toxic to the spores of fungi and thus prevent spore germination and infection. Relatively little attention has been paid to the effect of fungicides on the sporulation of such fungi.

Cucumber plants which had been inoculated, but on which the fungus had not as yet sporulated, were wetted and dusted either with sulfur or with copper-lime dust.[7] These plants were then placed in moist chambers together with other inoculated plants with the disease in the same stage of incubation, but without fungicides. The fungus sporulated normally on the leaves of plants without fungicides. There was some, but less sporulation on leaves of plants with copper dust. There was no sporulation on leaves of plants which had been dusted with sulfur.

In later experiments, detached cucumber leaves, showing the leaf spots symptomatic of infection by *P. cubensis*, but with no sporulation of the fungus, were wetted and divided into three groups of 50 leaves each. One lot was dusted with sulfur, one with copper-lime dust, and one received no fungicide. All were kept over night in a moist chamber at 18° C. and then examined for sporulation. Per unit area of leaf surface, conidia present expressed as relative numbers were as follows: on leaves without fungicide, 100; on leaves with copper-lime dust, 29 to 80; on leaves with sulfur dust, 0 to 5.

In these experiments, therefore, sulfur was much more effective than copper-lime dust in preventing sporulation. Some of the effect of sulfur on this fungus and the disease which it causes is due to its action in inhibiting sporulation, but it is evident that this effect alone is not enough to prevent infection of plants by a fungus the spores of which may be wind-borne from other plants which have not been sulfured, unless the fungicide is also effective in preventing spore germination. Such prevention of sporulation can prevent later infection only when there is no other source of inoculum from plants not sulfured, which may be the case in greenhouses here in fall and winter after all field-grown cucumbers have been killed by frost. This may explain in part the observation of Stone (43) that sulfur vaporized on heating pipes at least helps to prevent downy mildew of cucumber in greenhouses.

Effect of Sulfur on the Germination of the Conidia

Cucumber leaves infected with *P. cubensis* and bearing the conidiophores and conidia of this fungus were cut in half, and half of each leaf was dusted with sulfur. These and the unsulfured halves of the leaves, in neither case wetted, were placed in moist chambers (Wardian cases) at temperatures from 22° to 26° C. After intervals of time varying from 1¼ to 5 hours, conidia were removed and placed in water at a temperature of 18° C. Under these conditions, more than 60 per cent of the conidia from leaves not sulfured germinated. The percentage of sulfured conidia which germinated is shown in Table 4.

Exposure to sulfur for 5 hours at 22° C. or for 4½ hours at 24° C., with the sulfur in contact with the conidia and without precipitated moisture, prevented the later germination of these conidia.

[7] The sulfur used in these and later experiments was 300-mesh (98 per cent) dusting sulfur, and the copper-lime dust was one guaranteed to contain not less than 19 per cent monohydrated copper sulfate.

TABLE 4.—EFFECT OF SULFUR ON GERMINATION OF CONIDIA

Conditions of exposure to sulfur (dry)		Percentage of conidia which germinated when placed in water.
Temperature (°C)	Time (hours)	
26	1¼	50
26	2¾	22
26	4	7
26	4½	0
24	4½	0
22	5	0

For purposes of comparison, other downy mildew fungi were similarly used. It was found that the conidia of *Bremia lactucae* were killed by contact with dry sulfur for 6 hours at 23° C. and the conidia of *Peronospora effusa* (Grev.) Ces. were killed by contact with dry sulfur for 4½ hours at 26° C. Both Erwin (12) and Guba[8] have found that the conidia of *Bremia lactucae* may also be killed by exposure to vaporized sulfur.

Sulfur was toxic to the conidia of *P. cubensis* when applied dry as above described, but it was found to be non-toxic to them when they were in water. The conidia germinated freely when placed in water on micro-slides or leaves which had been dusted with sulfur. Kendrick (24) noted the same lack of effect of sulfur on the germination of the conidia of *Bremia lactucae* when they were placed in drops of water on a surface which had been dusted with sulfur. Copper-lime dust on the other hand was found by the writer to prevent the germination of the conidia of *P. cubensis* when used in water this way.

The water necessary for the germination of these conidia does not interfere with the fungicidal action of copper, but it prevents the toxic action of sulfur, at least to *P. cubensis* and to *B. lactucae*. This is naturally a very serious limitation to the value of sulfur for use against downy mildew of cucumber (and of lettuce), for it is least effective under conditions when it is most needed, that is, when there is water on the leaves. Sulfur does, however, have some slight fungicidal value against downy mildew of cucumber, as Weber (loc. cit.) concluded from his field experiments. This is attributable to its effects on the conidia in the absence of water, and on sporulation.

Protection of Cucumber against Downy Mildew by Sulfur and by Copper Fungicides

Sulfur is often used in the greenhouses of Massachusetts to control powdery mildew of cucumber, as recommended by Guba (15). The extent to which sulfur may also be effective, especially as compared with copper fungicides, in protecting cucumbers against downy mildew was, therefore, further investigated.

Infected cucumber leaves on which the fungus was sporulating were dusted with sulfur. These leaves and similar leaves not sulfured were placed in moist chambers at 25° C. for 4½ hours. Conidia were then washed from them and used to inoculate cucumber plants. Thirty drops of a suspension of sulfured conidia were placed on each of 20 plants, and conidia which had not been sulfured were applied in the same way to 20 other plants. Seven days later, there was an

[8]Guba, E. F. 1928. Mildew of lettuce. Jour. Market Garden Field Sta. of Mass. Agr. College, No. 95:4-5. (Mimeographed.)

average of 24 infection points per plant on the plants inoculated with conidia not sulfured, but there was no infection of plants inoculated with sulfured conidia. In a similar experiment, lettuce plants were inoculated with conidia of *Bremia lactucae* which had been in contact with sulfur (dry) for 6 hours at 23° C. No infection resulted, although there was abundant infection of lettuce inoculated with conidia from the same source but not exposed to sulfur. In these experiments, there was no water on the leaves when the sulfur came in contact with conidia.

In other experiments, leaves of cucumber plants were dusted with sulfur, and drops of water containing conidia of *P. cubensis* were placed on them. Under these conditions, infection was not prevented. As before, the behavior of *P. cubensis* in this respect was compared with that of another downy mildew fungus. Drops of a water-suspension of the conidia of *Bremia lactucae* were placed on lettuce plants after the plants had been dusted with sulfur, and under these conditions normal infection resulted. Copper-lime dust similarly used prevented all infection by both of these fungi.

In these and other experiments, partial protection of cucumbers was thus afforded by sulfur if the inoculum, conidia of *P. cubensis*, was made ineffective by the sulfur before the inoculum in water was present on a leaf. But if the conidia were in water on a leaf before the sulfur reached them, their germination and the resulting infection were not prevented. It seems evident that more reliance may be placed on sulfur for the control of downy mildew of cucumber in the greenhouse than in the field. It is true that in the greenhouse, leaves of cucumber may be wet at times (as by leaks, overhead watering, or water of guttation) and under these conditions, sulfur will not be effective; but in the field, leaves and conidia may be wet every dewy morning and under these conditions, sulfur is ineffective. It is then that copper fungicides are most valuable.

Earlier investigators are practically agreed that downy mildew of cucurbits as it occurs in the field, is profitably controllable by Bordeaux mixtures. Their conclusions have recently been cited by Weber (loc. cit.) and will not be reviewed here. Adams[9] and Weber (loc. cit.) have also found copper-lime dusts effective.

In experiments by the writer, sulfur and copper-lime dusts were applied to cucumbers in the field at intervals of 8 days beginning both before and after infection by *P. cubensis* (2 days after the first conidiophores were found on the leaves.) Plots dusted first before infection received two more applications than did plots dusted first after infection. Each plot was 10 feet wide and 100 feet long and plots were in triplicate. Average yields in pounds per unit area, expressed in relative numbers, are recorded in Table 5 for the years 1926 and 1927.

Sulfur did not increase yields, in fact its use was followed by yields lower than those of check plots. This means that sulfur not only failed to provide protection, but actually injured the cucumber plants to which it was applied. Plots which received early applications of sulfur did, however, yield more than plots first dusted with sulfur after the disease appeared, indicating that sulfur had some fungicidal effect, although not enough to offset its toxicity to the dusted plants.

Other investigators (53, 29, 15, 48) have also found that sulfur may be injurious to cucumbers and other cucurbits, especially muskmelon. Because of the susceptibility of greenhouse cucumbers to injury by sulfur if applied too

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[9]Adams, J. F. Downy mildew caused by *Pseudoperonospora cubensis*. U. S. Dept. Agr., Bur. Plant Ind., Plant Dis. Rptr., Sup. 34, pp. 202-203. 1924. (Mimeographed.)

TABLE 5.—EFFECTS OF SULFUR AND COPPER-LIME DUST ON YIELDS OF CUCUMBERS INFECTED WITH *P. Cubensis*

Plot treatments	Yields (expressed as percentages)	
	In 1926	In 1927
Check, no fungicide	100	100
Sulfur dust, applications begun after first infection	..	70
Sulfur dust, applications begun before first infection	..	94
Copper-lime dust, applications begun after first infection	102	157
Copper-lime dust, applications begun before first infection	168	197

heavily, Guba (loc. cit.) concluded that not more than 6 pounds of sulfur dust should be applied in a cucumber greenhouse 280 by 40 feet (for the control of powdery mildew). The same caution is suggested whenever greenhouse cucumbers are dusted with sulfur for any reason.

The dusting of greenhouse cucumbers with sulfur for the control of powdery mildew may, as discussed above, help to protect them against downy mildew also; but a copper fungicide, a Bordeaux mixture, is preferable if only downy mildew is to be combated. In the experiments of the writer, as in those in California[10] and Florida (48), sulfur did not satisfactorily control downy mildew of cucurbits under conditions favorable to the fungus, and similar results when sulfur was used were secured by Clayton (8) with downy mildew of lima bean, by Boyd (6) with late blight of potato, by Salmon and Ware (37) with downy mildew of hop, and in California (30) with downy mildew of lettuce. We may conclude that although sulfur is, of course, and generally, a valuable fungicide, this is probably not the case when downy mildews are to be combated.

In the field experiments, the results of which are summarized in Table 5, yields of cucumbers in 1927 were increased 97 per cent by copper-lime dust when the first applications were made before infection by *P. cubensis*, but only 57 per cent when the first applications were made after infection. Similar results were obtained the previous year, 1926, when yields were increased 68 per cent by copper-lime dust applied first before infection and only 2 per cent, or not significantly, when this treatment was first applied after infection. These results support the conclusions or recommendations of most earlier investigators (10, 42, 32, 48, 22, 7) to the effect that for maximum protection of cucurbits against downy mildew, it is necessary that fungicides be applied before rather than after infection.

Date of Beginning Applications

As has been observed by a number of investigators (9) (48, 42, 15), it is, however, quite possible to injure cucumber plants with Bordeaux mixture, and Clayton (9) and Zimmerly and co-workers (54) have found that young plants of cucumber and canteloupe, respectively, are more susceptible to such injury than are older plants. We may conclude that although cucumbers should be sprayed or dusted with a copper fungicide before infection, the first applications should not be made unnecessarily early. It is, therefore, important to know the approximate date at which the disease usually appears in the field in a given locality.

[10]U. S. Dept. Agr., Bur. Plant Ind. Diseases of field and garden crops in the United States in 1919. U. S. Dept. Agr., Bur. Plant Ind., Plant Dis. Rptr., Sup. 10, pp. 180-273. 1920. (Mimeographed.)

In each of the six years from 1925 to 1930 inclusive, downy mildew was looked for in cucumber fields of Hampshire County, Massachusetts, at intervals of 3 days beginning July 20 and continuing until the disease appeared. Downy mildew was first found here on August 15 in 1925, August 4 in 1926, August 6 in 1927, August 9 in 1928, August 18 in 1929, and August 11 in 1930. For six years, therefore, the disease always appeared here for the first time between August 4 and August 18, and this without any apparent relation to the date of planting or the weather of the season. On the basis of these observations, it is probable that field-grown cucumbers here need to receive treatment with a copper fungicide for protection against downy mildew beginning about July 25, but not before.

Frequency of Applications

The intervals of time between applications of a fungicide to plants are usually determined by the rate at which the plants grow and the rapidity with which the material is lost from the leaves as by weathering. It is frequently recommended that fungicides be applied "often enough to keep new growth covered." However, as has been shown, the youngest leaves of cucumber do not become infected with downy mildew, although these temporarily resistant leaves become susceptible as they grow older. *P. cubensis* is, under favorable environmental conditions, reproduced and disseminated very rapidly. On August 5, 1926, downy mildew was found on less than 2 per cent of the cucumber plants in a field of about 1 acre; on August 10 it was present on a little more than 50 per cent of the plants; and on August 15 every plant in the field was infected. It is evident that the intervals of time between applications of fungicides in such cases should not be long. Clayton (9) recommended that fungicides be applied to cucumbers in the field twice a week. In Massachusetts, however, adequate protection has been obtained with a copper fungicide applied 5 times at intervals of 8 days; and the disease was profitably prevented by Weber (loc. cit.) when applications of Bordeaux mixture or of copper-lime dust were applied at intervals of 1 week. This is considered to be often enough in this State.

Concentration of Bordeaux Necessary

Downy mildew of cucumber was controlled in the field by Bordeaux mixture 3:3:50 without injury to plants, and that is the concentration here recommended for use in the field. There may, however, be severe injury and stunting of the foliage of greenhouse cucumbers sprayed with Bordeaux mixture of this formula.

Many fungicides as used in the field are applied at a greater concentration than is actually required to prevent spore germination and infection. This practice may be necessary in the field, however, because of the gradual loss or removal of the effective constituent by rains or weathering. In greenhouses, the likelihood of such loss is at a minimum. With this consideration in mind, and because of the possibility of injury to greenhouse cucumbers by copper fungicides, the effects of each of several Bordeaux mixtures on infection of greenhouse cucumbers by *P. cubensis* was investigated.

Greenhouse cucumber plants (30 plants receiving the same treatment) were sprayed 3 times at intervals of 1 week using Bordeaux mixtures of the following formulas: 3:3:50, 3:10:50, 2:2:50, 2:10:50, or 1:1:50. Although there was in this case no real burning of foliage, the growth of plants sprayed with Bordeaux mixtures containing more than 0.25 per cent copper sulfate was retarded. All plants (including checks) were inoculated with *P. cubensis* 2 days after the

second application of fungicides. Every leaf of check plants without fungicide became infected. There was no infection of any of the plants sprayed with any of the Bordeaux mixtures, including the 1:1:50 formula. In these and other experiments of the writer, infection of greenhouse cucumbers by *P. cubensis* was prevented by Bordeaux mixture 1:1:50, and in these experiments, as in those of Guba (15), Bordeaux mixture 1:1:50 did not have the injurious effect on leaves of greenhouse cucumbers which sometimes follows the use of Bordeaux mixtures containing more copper. It is concluded that a Bordeaux mixture of the 1:1:50 formula is to be preferred to a more concentrated mixture when a fungicide is needed for the control of downy mildew of cucumber in greenhouses.

SUMMARY

Downy mildew caused by *Peronoplasmopara cubensis* is common and often severe on all varieties of cucumbers in both fields and greenhouses here. The fungus from cucumber was found to infect muskmelon, but not squashes, pumpkin, or watermelon. Cucumber is in no danger of infection by this fungus from weed hosts in this State. Youngest leaves of cucumber were found to be resistant to infection. The susceptibility of cucumber was not affected by applications of potash or lime to the soil.

No oospores or other wintering-over stages of the fungus have been found here, and inoculation of plants with material wintered-over in the soil has not resulted in infection. There is no relation between previous cropping systems and the occurrence of the disease here. The fungus enters greenhouses from fields in summer and fall, but it very rarely lives through the winter in greenhouses in Massachusetts. The fungus lives through the winter on living hosts in the South. All available evidence indicates that the fungus probably reaches Massachusetts from states farther south after a gradual northward movement by the aid of wind.

Conidia germinate in water, including dew and water of guttation. They were found to germinate at temperatures from 9° to 30° C. and to germinate best at 16° to 19° C. Infection took place at temperatures from 10° to 28° C. with most complete infection at 16° to 22° C. which was also about the optimum temperature for sporulation. Two to three hours on a wet leaf is long enough for germination. Conidia may emit zoospores and these may initiate infection, all within 5 hours. Length of life of conidia depends on moisture conditions. Some conidia remained viable for 50 hours in moist air.

Leaves which remained wet only 2½ hours were not infected, but there was some infection of leaves which remained wet 5 hours after inoculation.

Infection usually ends in sporulation within 6 to 9 days after inoculaton. Dew may provide enough moisture for sporulation. In dry air, the fungus may live in infected leaves for several weeks without sporulating.

Sulfur was more effective than copper-lime dust in preventing sporulation of the fungus. Conidia were killed by contact with dry sulfur for 5 hours at 22° C. Sulfur was, however, not toxic to these conidia in water. Infection was not prevented when the conidia in water fell upon leaves dusted with sulfur. Not only did sulfur fail to provide protection in the field, but it was also definitely injurious to cucumber plants. In both field and greenhouse copper fungicides are to be preferred to sulfur for the control of downy mildew.

Yields of cucumbers were increased more if copper-lime dust was first applied before, rather than after, infection. In Massachusetts, the first application of a copper fungicide should be made, in the field, about July 25. Later applications should be made at weekly intervals. Bordeaux mixture 3:3:50 is a sufficient concentration for use in the field. Bordeaux mixture 1:1:50 prevented infection of greenhouse cucumbers and, because of the possibility of copper injury, this is the concentration suggested for use in greenhouses.

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4M-6-32 No. 5709

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 284 MAY, 1932

Questions and Answers Concerning Pullorum Disease

By H. Van Roekel

The purpose of this bulletin is to make available for the Massachusetts poultry industry information which will aid the poultrymen to improve their methods of establishing and maintaining pullorum disease-free flocks.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

QUESTIONS AND ANSWERS CONCERNING PULLORUM DISEASE

By H. Van Roekel,[1] Chief of Laboratory
Poultry Disease Control

Introduction

Since numerous inquiries concerning pullorum disease have come to the attention of the laboratory, it has been deemed advisable to present this information in the form of questions and answers which should serve the needs of the Massachusetts poultry industry. In preparing this bulletin an effort has been made to present the information in such a manner that poultrymen will be able to understand the nature, eradication, and prevention of the disease.

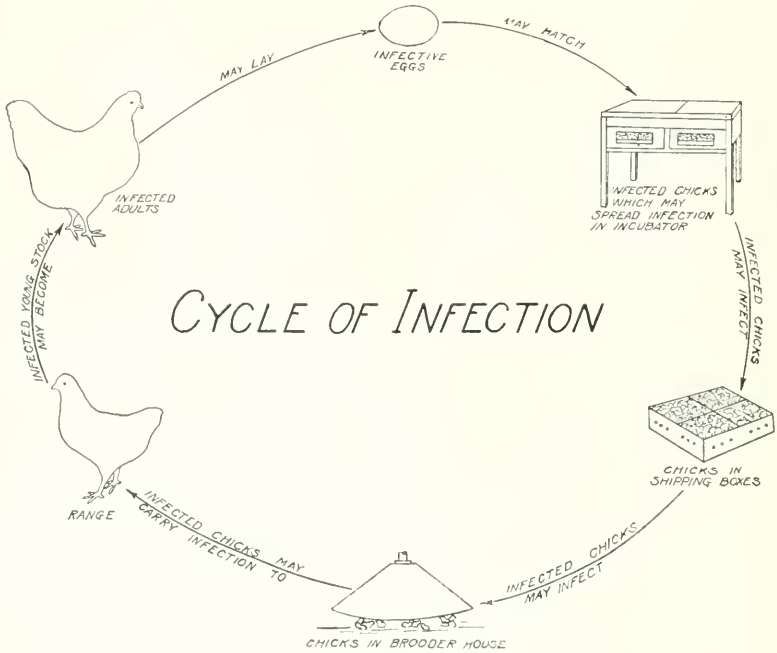


Figure 1.—Pullorum Disease Infection in a Flock May Follow This Cycle.

The disease can be eradicated either by breaking the cycle of infection through eliminating the infected birds by means of the macroscopic agglutination test, or by disposing of the entire infected flock and replacing it with pullorum disease-free stock.

[1]Assisted by K. L. Bullis, O. S. Flint, and Miriam K. Clarke. Appreciation is extended to Dr. John B. Lentz, Head of the Department of Veterinary Science, for the suggestions made concerning this bulletin.

History and Distribution of the Disease

1.—When was pullorum disease discovered? This disease was first reported late in the nineteenth century. In 1899, Rettger isolated the causative organism from infected chicks. The organism was first named *Bacterium pullorum* and the disease was designated bacillary white diarrhea. In 1925, the name of the organism was changed to *Salmonella pullorum*. In 1928, the name bacillary white diarrhea was changed to pullorum disease.

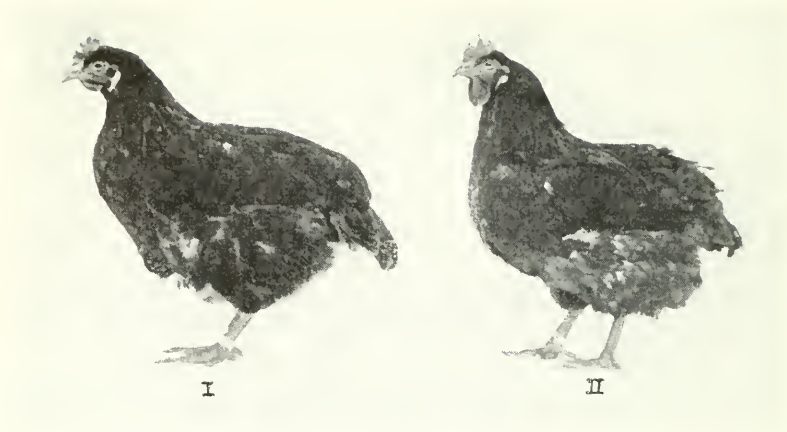
2.—What is the geographical distribution of the disease? Reports of the disease have come to our attention from England, continental Europe, Asia, Africa, Australia, Canada, and approximately every state in the United States.

Nature and Dissemination of the Disease

3.—What is the cause of pullorum disease? The cause is an infectious agent, a microscopic organism known as *Salmonella pullorum*.

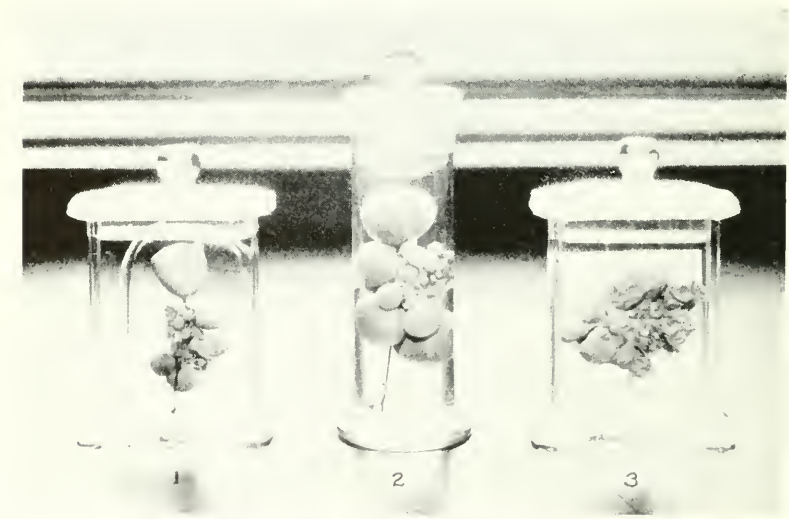
Photograph 1.—Salmonella pullorum, the Causative Organism of Pullorum Disease. The cells were taken from a 24-hour plain agar culture. Magnified 1200 x. Refer to question 3. (The author wishes to acknowledge his indebtedness to Dr. Theodore Soller, Amherst College, for taking this photomicrograph.)

4.—How does the disease affect adult birds? The disease usually manifests itself in adults in a chronic form. Infected birds as a rule cannot be differentiated from the non-infected by physical examination. While the organism may localize in various parts of the body, it is most frequently found in the ovary. Focal infections of this organism have been observed in the pericardial sac, lungs, remnant yolk stalk, spleen, testicles, ovary, abdominal cysts, and digital cushion of the foot. Frequently these focal infections break down, liberate the organism into the blood stream, and cause death of the bird. This seems to occur particularly when some debilitating process is present. Occasionally sporadic outbreaks of an acute form are observed in flocks and the disease pursues a definite course, accompanied by a high mortality.



Photograph 2.—Bird No. I—Non-infected Hen; Bird No. II—Infected Hen.

Pullorum diseased birds as a rule cannot be differentiated from the non-infected by physical examination. Apparently normal, well-developed birds may be affected with the disease. Infection in such birds can be detected either by the agglutination test or by bacteriological examination. Refer to questions 4 and 33.



Photograph 3.—Ovaries Removed from Hens.

Specimens I and III, showing irregular shaped, discolored and pedunculated ova, are affected with pullorum disease. Specimen II, showing normal ova, is not affected. Refer to question 4.

5.—Can the disease spread among adult birds? Yes. Non-infected adults may contract the disease when placed in contact with infected birds. The rate of spread is influenced by the condition of the flock and type of management, but generally speaking it appears to be slow.

Photograph 4—Oviduct Removed from an Infected Hen.

Parts I and II are the funnel and albumen secreting portions of the oviduct, respectively. The funnel or fimbriated portion shows an enlarged and thickened wall. The albumen secreting portion (anterior end) is impacted with hard, dried egg material. The exterior surface of the impacted region is roughened due to inflammatory conditions. Such changes may be found occasionally as a result of inflammation of the oviduct and other abdominal organs. Part III is the shell gland portion. Refer to question 4.

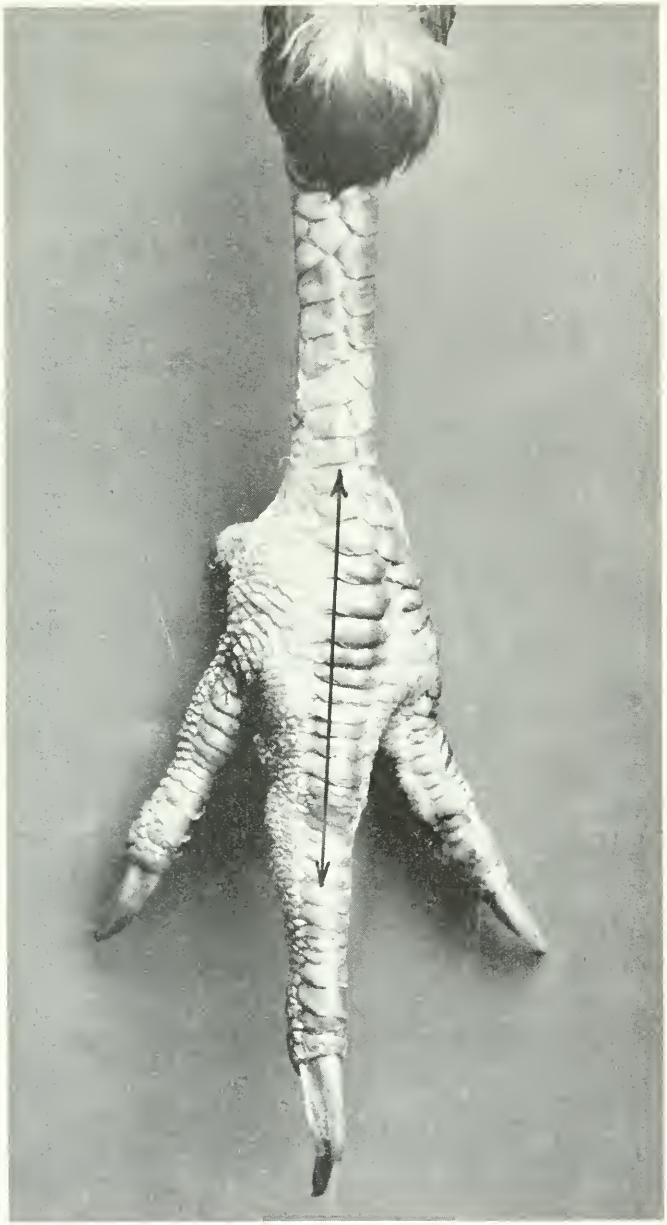
6.—**Are male birds affected?** Yes. Males may contract the disease. The percentage of reactors among tested males appears to be less than among tested females. It is probable that the sex difference is not the only factor responsible for the difference in the percentages of reactors.

7.—**Do males play a role in dissemination?** Conclusive evidence is not available to show that males spread the disease. Focal infections have been observed in the testicles. Also, one might assume that the infected male could eliminate the organism in the droppings, as occurs in diseased females. Furthermore, males might act as mechanical carriers in transmitting the organism from the cloaca of an infected female to the cloaca of a non-infected female.

Photograph 5.—The heart on the left is apparently normal and was removed from a non-infected hen. The heart on the right shows enlargement, thickening of the heart sac, and roughened heart surface. S. pullorum was isolated from the pericardial fluid. Refer to question 4.

8.—**What is a pullorum disease "carrier"?** A "carrier" is an infected bird that has not succumbed to the disease during chickhood or has become infected before or during maturity.

9.—**How is the organism eliminated by adult birds?** The organism may be eliminated by means of the droppings (secretions and excretions from the digestive, urinary, and reproductive tracts), by eggs, abrasions in the skin,

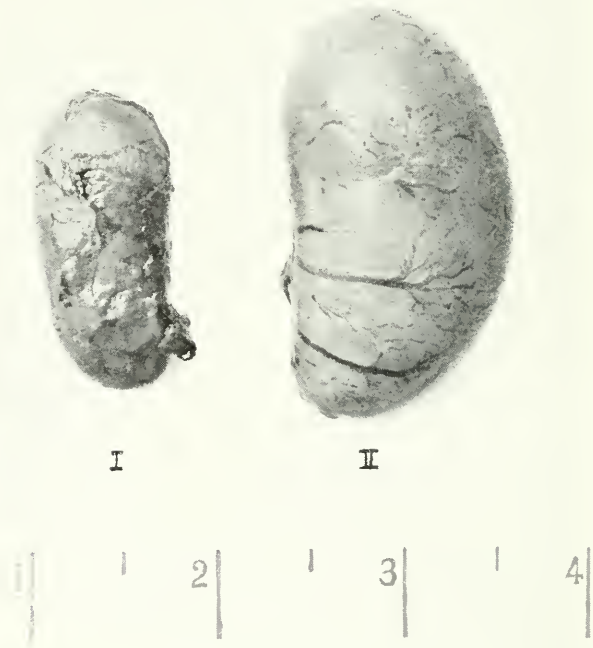


Photograph 6.—Lower Portion of a Leg of a Pullorum Disease Reactor.

Note the enlargement of the foot in the region of the arrow. The pad of the foot had an abrasion in the skin which was covered with a scab. S. pullorum was isolated from pus in the region of the digital cushion. Refer to question 4.

and possibly from the mouth, nostrils, and eyes. The organsim has been isolated from an abscess in the foot, which at one time appeared to have communicated with the exterior. The organism has also been found in the respiratory system. According to investigations, the presence of the organism has been observed in eggs and droppings.

10.—Through what avenues may birds become infected? Birds have been infected by way of the digestive and respiratory tracts, eyes, abrasions in the skin, and cloaca.

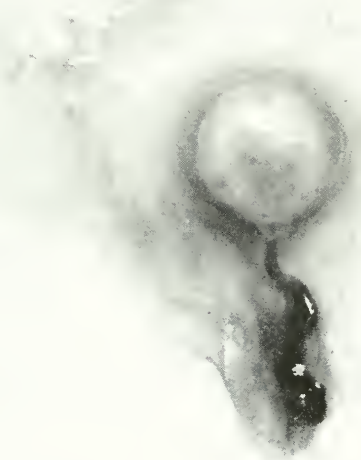


Photograph 7.—Testicles Removed from a Reacting Adult Male.

Testicle No. I appeared to be functioning even though its structure was firm and its size greatly reduced. S. pullorum was isolated from this testicle. Testicle No. II appeared to be normal in size and texture. S. pullorum was not isolated from this organ. Refer to question 7.

11.—How may infection be introduced into an adult flock? The disease may be introduced into an adult flock through buying infected stock, returning birds from shows or contests, using equipment (bird and egg crates, feed sacks, etc.) that may have been contaminated elsewhere; feeding infective eggs; and feeding garbage which might contain infective eggs or offal of infected birds.

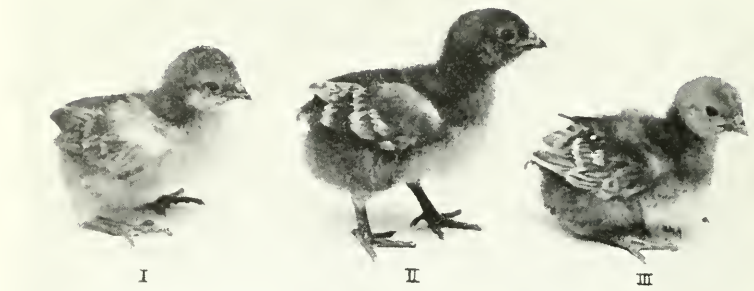
12.—May adult birds contract the disease by eating fresh eggs laid by infected hens? Yes. Investigations have shown that birds may contract the disease by eating infective fresh eggs. In some flocks one frequently observes birds that have formed a habit of egg-eating. This habit may have been acquired as a result of birds laying the eggs on the floor or dropping board. At present the most important means of spread among adult flocks appears to be through eating infective fresh eggs.



Photograph 8.—An ovum (abnormal in color, size ,and shape) was found in an infertile egg which contained an apparently normal yolk. Note the dark peduncle which was its means of attachment to the ovary. S. pullorum was isolated from the amber colored, caseated contents of this ovum. Enlarged 2x. Refer to question 9.

13.—Can the disease be transmitted through the egg? Yes. Infective eggs used for hatching purposes transmit the disease to the chicks. Feeding of infective eggs to chicks will infect them.

14.—How does the disease affect young chicks? The disease may manifest itself within a few days after hatching. The following symptoms may be observed: depressed vigor, loss of appetite, a tendency to remain under the hover, frequent cheeping, droopy wings, shortened bodies, pasting of the vent



Photograph 9.—Nine-day-old Chicks Free of Pullorum Disease.
Chicks I and II are males and III is a female. Refer to question 14.

with white chalky excreta, marked depression and exhaustion followed by death. These symptoms are neither characteristic nor specific for pullorum disease alone, since they may be observed in other health disturbances of chicks. The mortality rate may vary from low to as high as 100 per cent. Losses may be observed within two or three days after hatching and may continue until the chicks are three weeks of age or older. The greatest losses usually occur during the second week of chickhood. The onset and severity of the disease depend upon the amount of infection in the body, the ability of the organism to produce the disease, the resistance of the chick, and the care given by the poultryman. In some cases diseased chicks show little or no evidence of infection, while in other cases all the possible manifestations of the disease are found.

Photograph 10.—Nine-day-old, Naturally Infected Pullorum Diseased Chicks.

Shortened bodies, pasting of the vents with excreta, droopiness and drowsiness are symptoms manifested by these chicks. Chick III died two days after it was photographed. S. pullorum was isolated from chicks II and III. Chicks I and II are males and III is a female. Refer to question 14.

15.—Can the disease in young chicks be accurately diagnosed without bacteriological examination? No. The symptoms and lesions are neither characteristic nor specific of pullorum disease alone.

16.—Why is an accurate diagnosis important? An accurate diagnosis will make it possible for the owner to follow proper eradication plans. An inaccurate diagnosis of pullorum disease may be responsible for unwarranted efforts and expenditures or cause further dissemination of the disease and delay eradication. One must recognize that for infected and non-infected flocks the plans of management should not be the same in order to obtain effective and profitable results.

17.—Where may chicks be sent for diagnosis? Massachusetts flock owners may submit chicks to the Department of Veterinary Science, Massachusetts State College, Amherst, Mass.

18.—How should diseased chicks be submitted to the laboratory? Five typical specimens affected with the disease, freshly killed and chilled (to retard decomposition) should be packed in a suitable container, well insulated, and placed in the mail so as to permit arrival in the shortest possible time.

19.—Does the disease spread among chicks? Yes. The disease may spread among chicks in the incubator, chick box, and brooder. In the incubator the chick may be infected by inhaling or eating contaminated material. In the chick box and brooder the spread occurs largely through the digestive tract by eating or pecking contaminated droppings, litter, feed, and water.

20.—How may infection be introduced into the chick flock? The purchase of infective eggs or stock, custom hatching for infected flocks, having eggs hatched where infection exists, feeding of infective eggs, using contaminated equipment (sacks, chick boxes, egg crates, etc.) and contact with infected adult stock, are means of introducing infection into a chick flock.

21.—Can persons spread the disease? Yes. The caretaker may spread the disease in the handling and feeding of the chicks. Contaminated droppings, litter, and feed may be carried from infected chicks to the non-infected chicks. The possibility of a person carrying infection from one farm to another appears to be rather remote, unless he carries with him contaminated material which might be capable of infecting chicks. To safeguard against this it is advisable to prohibit visitors from entering the egg room, incubator room, and brooder houses.

22.—Are all birds equally susceptible? No. Artificial exposures have shown that there is a variation in the degree of susceptibility to the disease among both chicks and adults.

23.—Do certain breeds appear to be less susceptible? Opinion has been expressed that the lighter breeds appear to be less susceptible. However, testing records show that heavy infection has been observed in flocks of all common breeds.

24.—Are fowl other than chickens susceptible? Natural infection has been reported among turkeys, pheasants, sparrows, bull-finch, goslings, and ducklings. Artificial infection has been produced in pheasants, guinea fowl, pigeons, canary birds, and sparrows.

25.—Are mammals susceptible to the disease? Guinea pigs, mice, rats, cats, and especially rabbits are susceptible to artificial infection. Natural infection in rabbits has been reported.

26.—Is man susceptible to the disease? The disease has not been reported in man as a result either of eating infective eggs or of handling infected stock.

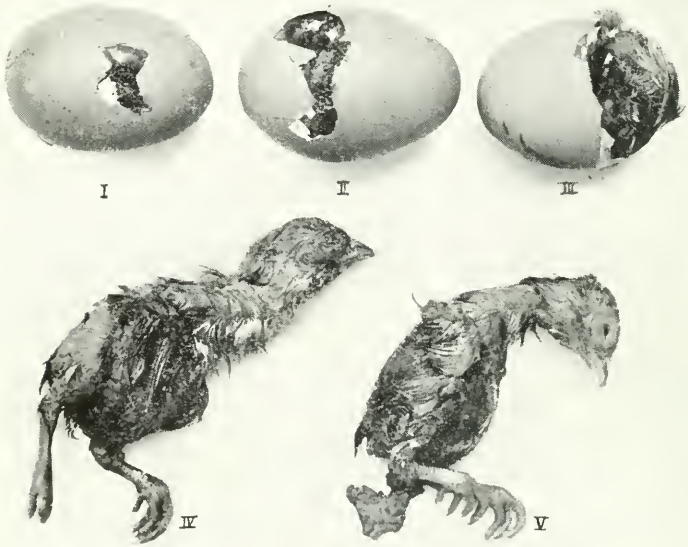
Losses Due to Pullorum Disease

27.—Do adult flocks suffer a mortality from this disease? Yes. Occasionally a high mortality may be experienced when the disease develops into an acute form. Carriers in general do not possess the disease resistance of normal birds; therefore, a higher mortality is observed among carriers than among healthy individuals.

28.—Is egg production affected? Yes. Investigations have shown that infected birds do not lay as well as non-infected birds. This may be accounted for by the diseased ovary, underdevelopment, and low disease resistance of the bird.

29.—Are fertility and hatchability affected? Yes. The percentages of fertility and hatchability are markedly reduced.

30.—Do chicks suffer a mortality? Frequently high mortalities, sometimes as high as 100 per cent, are observed among infected chicks and infrequently little if any mortality is observed. Overheating, chilling, overcrowding, and insanitary conditions markedly influence the mortality rates.



Photograph 11.—Dead Embryos.

Pullorum disease affects hatchability. At the end of the incubation period, embryos may either be dead in the shell or be too weak to emerge from the shell. Embryos IV and V were removed from the shell on the twenty-first day of incubation. S. pullorum was isolated from embryos III, IV, and V. Pullorum disease should not, however, be regarded as the only cause responsible for low hatchability. Refer to question 29.

31.—Do infected chicks mature normally? In severe outbreaks the normal development is markedly affected, as shown by a lack of uniformity of growth and underdevelopment of birds.

Photograph 12.—Six-weeks-old Chicks Exposed to Pullorum Infection When 72 Hours Old
Weights: No. 1, 115 grams; No. 2, 488 grams; No. 3, 193 grams.
Pullorum disease has an influence on the rate, uniformity, and amount of growth. Refer to question 31.

32.—Does the presence of the disease affect the salability of eggs and stock? Yes. The public has been and is being educated to buy only pullorum disease-free stock. A buyer who has had the unfortunate experience of buying and losing infected chicks will avoid repeating that experience if at all possible. A poultryman who has spent several years in developing a pullorum disease-free flock of good breeding, and then unthinkingly or unknowingly introduces infection, will suffer a great loss not only through the cost of eradicating the disease, but also from reduced sales.

Control and Eradication of the Disease

33.—Can the disease be eliminated by culling birds that lack vigor and vitality? No. "Carriers" of the disease are not always the poorest individuals in the flock. Apparently normal, well-developed birds may be infected with the disease.

34.—Is incubator disinfection effective in eradicating the disease? Incubator disinfection, while partially effective in decreasing the spread of the disease in the incubator, should not be encouraged as a means of controlling or eradicating the disease because it is unable to destroy the organisms in the live chick. Infected live chicks are spreaders of the disease, and complete control or eradication requires the elimination of the spreader. Therefore, poultrymen who have outlined an incubator disinfecting program with the intention of eradicating this disease, can expect but one result, which is failure in eradication.

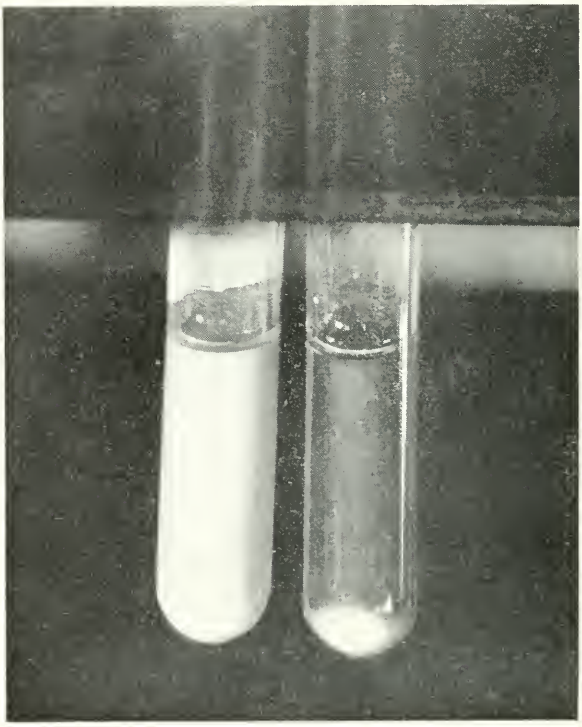
Incubator disinfection should be regarded as part of the general sanitary program and not as a disease eradication measure in itself.

35.—How may carriers of this disease be detected? Infected birds may be detected by the following tests: Intradermal test; macroscopic agglutination test; rapid serum agglutination test; and whole blood agglutination test.

36.—What is the intradermal, pullorin, or "wattle" test? This test consists of injecting a biological preparation into the skin of the wattle. If a swelling appears at the point of injection within a certain limit of time, the bird is regarded as infected.

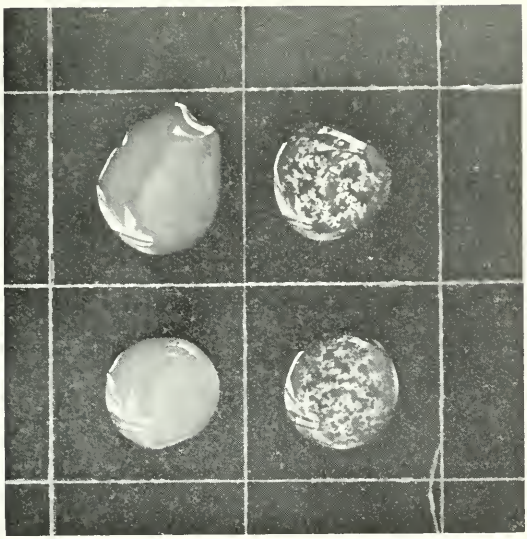
37.—Is the intradermal test reliable in eradicating infection from a flock? Leading investigators are of the opinion that the test in its present state is not as reliable as other tests which are employed for eradication of the disease.

38.—What is the macroscopic tube agglutination test? In general this test consists of the following steps: all birds are legbanded; a small amount of blood is taken from the bird and the sample labelled with the legband number; a small portion of serum is removed from the blood sample to a tube containing



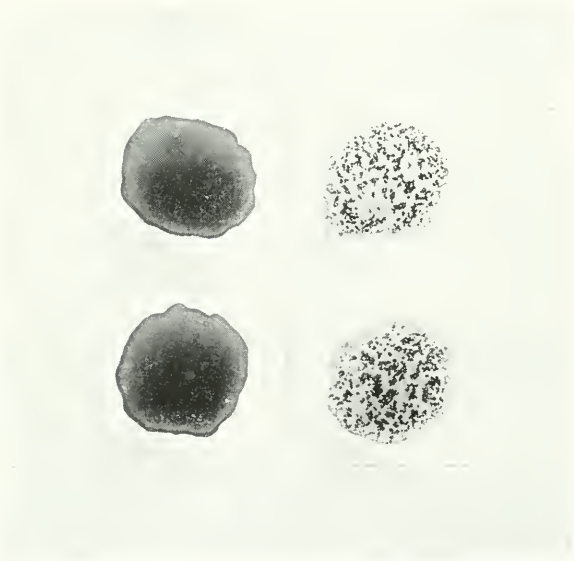
Photograph 13.—Macroscopic Tube Agglutination Test.

The tube on the left shows a negative reaction, and the tube on the right shows a positive reaction. Refer to question 38.



Photograph 14.—The Rapid Serum Agglutination Test.

The mixtures in the squares on the left show a negative reaction, and the mixtures in the squares on the right show a positive reaction. Refer to question 39.



Photograph 15.—The Whole Blood Agglutination Test.

The mixture in the squares on the left shows a negative reaction, and mixtures on the right show a positive reaction. Refer to question 40.

turbid test fluid; the serum and test fluid are thoroughly mixed, the mixture is incubated for 24 hours or longer at body temperature; and the results are recorded at the end of the incubation period. A test is regarded as positive when a deposit has formed in the bottom of the tube with the test fluid partially or completely clear, and upon shaking of the tube the deposit breaks up into fine clumps. In a negative test the turbidity of the mixture is not changed. All birds whose samples react positively are reported as reactors or "carriers." These birds are removed from the flock and slaughtered for meat.

39.—What is the rapid serum agglutination test? This test is a modification of the tube agglutination test. A small amount of serum taken from the blood sample is placed on a glass plate. To this serum is added a small amount of test fluid whose turbidity is far greater than that of the test fluid used for the tube method. The serum and test fluid are mixed by stirring and after a few minutes the result of the test is recorded. A test is positive when definite white clumps form in the serum-test fluid mixture. In a negative test the serum-test fluid mixture remains uniformly turbid.

40.—What is the whole blood agglutination test? The whole blood agglutination test consists of mixing whole fresh blood or whole dry blood with a stained test fluid which is quite similar to that employed for the rapid serum method. The results are recorded within a few minutes after the blood and test fluid are mixed. A positive test is indicated by definite clumps floating in the mixture. A negative test shows no clumping. This test is used on the premises, usually in the poultry house, and tested birds are retained in trapnests or improvised retention coops until the results of the test are recorded. This makes it possible to remove positive birds from the flock immediately.

41.—Have any of these tests been adopted as standard? At the present time, the macroscopic tube agglutination test is regarded as the standard test for detecting pullorum disease carriers. This standard test is subject to modification or change when a more effective, inexpensive and efficient method or test is discovered for pullorum disease eradication.

42.—Has a test been developed which has proved practical and reliable in the hands of poultrymen? At the present time, no test for pullorum disease eradication is recognized as reliable and effective when placed in the hands of poultrymen or persons not properly trained. The different tests are of such a nature that they require thorough knowledge in the fields of biological sciences in order to obtain most expeditious and successful results in eradication of the disease. The results of a test must be judged by the quality of the operator and the methods employed.

43.—What is a reactor? A reactor is a bird whose serum gives a doubtful or positive reaction in the serum-test fluid dilution of 1-25 after 24 hours' incubation at body temperature. If only doubtful birds are found, they are subjected to further examination. Postmortem examinations are often helpful in making a diagnosis.

44.—Do infected birds always show a positive agglutination test? Occasionally infected birds are discovered at necropsy that did not react positively to the agglutination test. The serum dilution (proportion of serum to test fluid) is an important factor in detecting such birds. The lower the dilution the more infected birds will react. Infrequently, some birds may react at one test and not at the next. Due to this fluctuation in reactions they are called intermittent reactors.

45.—Are non-reacting infected birds considered as spreaders? Investigators have found the causative organism in eggs laid by such birds. The organism has also been isolated from the ovary and other organs on necropsy. Fortunately such birds are rare, as shown in flocks which are tested annually.

46.—Are all reactors infected with the organism? Reacting birds are observed in which no gross signs of the disease can be found. Few such birds are found infected on bacteriological examination. A plausible explanation for failure to isolate the organism from some reacting birds is that such birds either have been infected recently or the organism has been eliminated recently. However, it must also be recognized that the methods of examination have their limitations.

47.—Do all reactors lay infective eggs? No. If the infection is localized in those parts of the body which have no direct relation or communication with the oviduct, the organism is not eliminated through the egg. Furthermore, not all eggs laid by an infected bird contain the organism.

48.—Should fresh eggs from infected or untested flocks be fed to non-infected stock? No. Investigations have shown that birds may be infected when fresh eggs laid by infected birds are fed.

49.—Why do negatively reacting birds suddenly become positive reactors? Non-reacting birds that suddenly react positively, in all probability have been infected recently. Artificial infection has shown that birds may first react between the fourth and seventh day after the first exposure. The avenue of infection, the size of dose, the ability of the organism to infect the bird, the resistance of the bird, and the ability of the bird to produce antibodies are factors that determine the reaction of the bird.

50.—Should the flock be tested annually? Yes. Poultrymen who use part or all of their flocks for breeding purposes should test all birds on the premises each year. The test is a means of detecting infected birds. It does not assure the owner that once his flock is free of infection it will remain free. Flocks do become re-infected, and through annual testing the infection is detected and eliminated before it has an opportunity to cause great losses. Therefore, annual testing is necessary to determine, from year to year, the status of the flock in regard to this disease.

51.—At what age may birds be tested? Reactors have been detected among chicks seven days of age or older. However, infected chicks do not all react at this age period. Birds tested between four and twelve weeks of age will show a larger percentage of reactors than if tested at a younger age. On the other hand, some young birds detected as reactors may become negative towards maturity. Since this disease will be disseminated as long as infected birds are present, the purpose should be to eliminate the majority if not all of the infected birds at the earliest practical age. Birds three to four months of age may be tested successfully.

52.—Should birds attain egg production before they are tested? Since the majority of infected birds can be detected before they attain egg production, it is advisable from an eradication point of view to eliminate the infected birds before they attain egg production in order to prevent the spread of the disease through the eating of infective eggs laid by diseased birds. Furthermore, elimination of infected birds at an early age will also prevent dissemination by other means common in a diseased flock.

53.—Can birds be tested on range? Birds may be successfully tested on range provided suitable facilities are available. Range testing is recommended for infected flocks so that the bulk of the infection will not be moved into the laying quarters where the birds are more congested and there is greater opportunity for spread of the disease.

54.—Is it necessary to test all birds on the premises? To determine the exact disease status of the entire flock it is necessary to test all the birds on the premises.

55.—Is it safe to retain a few untested culls on the premises for a short time after the test? Untested culls should always be regarded as dangerous to the tested flock even under the best of quarantine conditions. The safest procedure is either to cull and dispose of the undesirable birds before the test or to test all the birds on the premises.

56.—Is it safe to retain untested birds in separate houses for egg and meat production? No. The practice of keeping untested birds on the premises for egg and meat production is one of the causes for failure to establish or maintain a pullorum disease-free flock. Most poultry plants are so organized and managed that no quarantine measures could be successfully executed on the two types of flocks.

57.—Why should the entire flock be tested at one visit? Testing of the entire flock at one visit permits the flock owner and the blood collector to check more accurately whether all the birds have been tested. It prevents untested birds from mixing with tested birds. It assures more economical and satisfactory routing of the blood collector.

58.—How should tested birds be marked? All tested birds should be banded with an official sealed band in order that their future identification can be accurately associated with their testing history.

59.—Is retesting advisable in infected flocks? In retesting infected flocks one should consider the value of the stock, the amount of infection, and the arrangement and the mode of operation of the plant. The value of the stock is probably the primary consideration. If the value does not warrant the expenditure for retesting, then the inferior infected flock should be sold and replaced with pullorum disease-free stock. In the majority of cases when the flock is heavily infected, retesting is not advisable because the size of the flock will be reduced to such an extent that a profitable breeding program cannot be followed. Furthermore, the eradication of infection often appears to be more difficult in such cases than where the amount of infection is small. Sometimes the arrangement and operation of the plant are such that a retesting program cannot be applied effectively. If the nature of the flock and condition of the plant do not warrant or permit effective retesting, then the flock should be replaced with pullorum disease-free stock.

60.—How many tests are necessary to eradicate the disease from a flock? The number of tests required to eradicate the disease is influenced by the condition of the birds, the amount of infection, the conditions and the management of the plant and the quality of the test. In Massachusetts five retests within one season have been the maximum number necessary to eliminate the infection from a flock. In some flocks only two retests were necessary.

61.—Should infected or reacting birds be culled as soon as detected? Yes. Infected or reacting birds should always be regarded as spreaders of the disease. Therefore, immediate culling and disposal of such birds is recommended.

62.—Why should reactors not be retained for egg production? Reactors retained for egg production are a constant source of danger to the non-infected birds on the premises. The possibility of the reactors coming in contact directly or indirectly with the non-infected birds always exists. Eradication of the disease from the premises cannot be accomplished as long as reactors or infected birds are retained on the premises.

63.—What disposition should be made of reactors? Reactors should be sold only for slaughter. Offal and waste should be properly handled to prevent the spread of the disease.

64.—In case of a few reactors, is home slaughter objectionable? Home slaughter may be practiced if the reactors are slaughtered immediately after being detected and if proper disposal is made of the waste and offal. However, the safest prodecure is to sell the reactors to a slaughtering plant.

65.—Is feeding offal from dressed birds to animals a dangerous procedure? Feeding offal from dressed birds to animals is an unsound procedure because they may either become infected or act as mechanical carriers and in that manner disseminate the disease.

66.—What disposition should be made of dead adult birds, waste, and offal, infertile and unhatched eggs, and dead chicks? Such materials should be burned which will destroy all forms of life. An incinerator of some sort should be considered a necessary fixture on each poultry plant. Burying is not recommended unless the materials are placed at such a depth that they will not be disturbed and lead to further dissemination of the disease.

67.—Is it necessary to clean and disinfect premises after reactors are removed? Thorough cleaning and disinfection of the houses following the removal of the reactors is a very important and necessary step in an effective eradication program. The sanitary aspect of a poultry plant should not be neglected, as is very often the case.

68.—What disinfectant should be used? Any of the "permitted" disinfectants approved by the United States Department of Agriculture are applicable for general disinfection of poultry houses and equipment. Poultrymen have access to the list of "permitted" disinfectants through their local county agents.

69.—Should owners of pullorum disease-free flocks practice custom hatching? The owner of a pullorum disease-free flock should strive to prevent the introduction of disease into his flock. This may be accomplished with the greatest degree of certainty by eliminating all possible disease hazards. If the owner is not certain that his customers are supplying non-infective eggs, custom hatching is a disease hazard to his flock.

70.—Should owners of infected or untested flocks practice custom hatching? Investigators have shown that infection may spread in the incubator, and in order to prevent the dissemination of the disease, the practice of custom hatching eggs from infected or untested flocks must be condemned. The first consideration for such owners should be to establish a pullorum disease-free flock, which will be for the good of the industry as well as for their benefit.

71.—What dangers are associated with the practice of having eggs hatched away from the premises? The owner who follows this practice subjects his flock to the same hazards as the owner who does custom hatching. In fact it may be a more dangerous practice because he has no control over customers supplying eggs to the same hatchery. A thorough investigation of the pullorum disease standing of the flocks and the business integrity of the customers should be made to assure the maximum elimination of hazards. However, even with the utmost care, one may introduce infection through this practice.

72.—If new stock is desired, what kind should be selected? In selecting new stock, the first consideration is health. Adults, chicks, and eggs should be selected that are free of infection. Such stock may be obtained from recognized pullorum disease-free flocks.

73.—What is generally regarded as a pullorum disease-free flock? A pullorum disease-free flock is a flock in which no reactors were detected by the macroscopic tube agglutination test on two successive tests not less than six months nor more than a year apart.

74.—Who should be consulted in the purchase of pullorum disease-free stock? Whoever is in the position to give reliable and official testing information regarding the flock, aside from the owner. No flock owner should resent having his statements checked. In Massachusetts, testing information may be obtained from the local county agent.

75.—Why should buyers check advertisements? Frequently claims in advertisements are incomplete, misleading, and false. The purchase of stock should not be based upon the claims in the advertisement without investigation.

76.—Do terms such as "tested stock"; "100 per cent clean"; "state tested"; "accredited"; "certified" mean freedom from pullorum disease? Such terms are indefinite and misleading in regard to the pullorum disease standing of a flock. The terms "tested stock" and "state tested" do not inform the reader about the particular disease and the results of the test. The term "100 per cent clean" does not state the disease in question. In certain states the term "accredited" has been given to flocks designated as "certified" in other states. Considerable confusion has resulted from this. The terms alone do not have any meaning unless one is familiar with the regulations that define these terms and the thoroughness of the execution of the regulations. Therefore, one should investigate carefully the significance of such indefinite terms.

77.—Who can assist in determining the validity of the advertisement? In Massachusetts, the county agent is able to assist in checking the validity of claims in advertisements. In other states, either the control or the testing agency should be consulted.

78.—Are the tested flocks in Massachusetts classified according to their pullorum disease status? Flocks that have qualified for certain breeding and testing requirements are eligible for certification. Flocks are certified for one year only. Copies of testing results of all tested flocks are submitted to the certifying agency by the testing laboratory. The certifying agency operates independently of the testing agency. County agents are provided with testing summaries of flocks in their local counties.

79.—Where may information concerning certification be obtained? Inquiries concerning certification should be submitted to the Massachusetts Department of Agriculture, State House, Boston, Mass.

80.—How should tested flocks be classified as to their pullorum disease status? Tested flocks in reality are either infected or pullorum disease-free. However, in a disease of this nature, it is not always safe to declare a flock free of the disease when only one negative test has been obtained. Therefore, two successive negative tests not less than six months nor more than a year apart appear to be a safer index in determining the true status of a flock. Nevertheless, a flock which has passed one negative test should be given more recognition than a tested flock which has revealed reactors. The latter flock should be regarded as infected and unsafe for breeding purposes.

81.—Are other measures aside from the agglutination test important for successful eradication? Yes. The agglutination test is only one step in an eradication program. Prompt removal of reactors and sanitary and preventive measures must be observed in establishing and maintaining a pullorum disease-free flock.

82.—What is necessary for successful eradication? Successful eradication is based upon the adoption of sound, effective, and uniform methods, properly and skillfully executed. A sound eradication program for the individual flock or for the poultry industry as a whole should include measures that will prevent the spread of the disease (through various channels as discussed in this bulletin) and permit effective eradication of the disease. The adoption of such methods is no more important than their proper execution. Control officials and poultrymen should not expect to attain their goal in eradication if the measures are not justly put into practice. Too frequently either delay or failure in eradication is due to faulty execution of recommended measures. The following measures should be observed in establishing and maintaining a pullorum disease-free flock:

a. All birds on the premises should be tested each year.

b. If infection is present, the entire flock should be retested within four to six weeks until a negative report is obtained, provided the value of the birds justifies the expenditure for testing.

c. Every reactor, regardless of its value, should be removed from the premises and sold for slaughter immediately upon receipt of the report.

d. Offal from all birds dressed for market or home consumption as well as dead birds that are not fit for consumption should be burned.

e. The poultry houses, runs, and equipment, should be thoroughly cleaned and disinfected immediately after removal of reactors. Provide an empty pen to each house to facilitate cleaning and disinfection during the winter months. Use disinfectants approved by the United States Department of Agriculture.

f. Birds removed from the premises to egg-laying contests, exhibitions, etc., should be held in quarantine and determined free of disease before they are re-admitted into the flock.

g. Purchase of stock in the form of adults, chicks, and eggs should be from known pullorum disease-free flocks.

h. Eggs should not be saved for hatching until after a flock has been tested and all the infected birds removed. Early pullet testing will permit early hatching.

i. Fresh and infertile eggs from unknown or infected sources should not be fed to chickens or exposed to other animals that may carry or spread the infection.

j. Poultrymen should not custom hatch for untested or infected flocks.

k. Owners of pullorum disease-free flocks should not have hatching done where infected eggs or stock may be found.

l. Poultrymen should not buy feed in bags that have been used or exposed to infection. (Such bags if properly disinfected will be safe for further use.)

m. Poultrymen should not use equipment that has been exposed to or contaminated with infective material.

83.—Why are sound, effective, and uniform methods of control and eradication necessary? Such methods are necessary to create faith and confidence in the eradication results upon which a profitable poultry industry rests.

84.—Can reliable and uniform methods of eradication be instituted if poultrymen test their own flocks? No. At the present time, no simplified test has been discovered which can be placed in the hands of poultrymen and yet give reliable results. Uniformity of technique and interpretation of results would be sacrificed. The results of a test are no better than the ability and integrity of the person conducting the test.

85.—When should new stock be tested and retained in quarantine before being admitted into the flock? In respect to pullorum disease, new stock received from doubtful sources should be retained in quarantine and pass two negative tests at least four weeks apart before being admitted to the flock. Frequently poultrymen fail to observe this measure and as a result introduce infection into their flocks. The purchase of new stock from doubtful sources is not recommended as a sound practice in poultry husbandry.

86.—Should birds employed for exhibition and contest purposes be returned to the premises? From the aspect of disease prevention, it is not advisable to return such birds to the flock. However, if for breeding purposes their return is really necessary, then they should be retained in quarantine and pass two negative tests at least four weeks apart before being admitted to the flock. Poultrymen attach too little significance to the introduction of disease through this channel.

87.—Are any losses associated with testing due to bleeding and handling of birds? Very seldom birds die as a result of loss of blood. A decrease in egg production has been observed in some flocks. However, losses associated with the collecting of blood samples should be negligible if the flock is healthy and properly handled.

88.—Why is the flock owner requested to report the condition of his flock prior to the arrival of the blood collector? The flock owner is requested to report the condition of his flock in order to prevent the unnecessary exposure of the blood collector to disease outbreaks. Furthermore, the most important reason is to prevent the disturbance of diseased flocks, which is beneficial to the diseased and healthy birds. Delayed notification of the flock condition causes great inconvenience in routing the blood collector and consequently increases the cost of testing.

89.—Is there danger of the blood collectors spreading the disease? Blood collectors are given instructions designed to prevent the spread of the disease from plant to plant. The field operations of the blood collector are checked from time to time by a laboratory representative. Flock owners are requested to report to the laboratory when blood collectors do not observe precautions.

90.—What is the resistance of the causative organism to various environmental conditions? Investigators have reported that the organism may remain alive in artificially inoculated soil for approximately fourteen months and in carcasses for at least thirty days. On dry cloth, retained at room temperature, it has remained alive for at least 26 weeks. In chick feces it remained alive for approximately 101 days. When subjected to the ordinary disinfectants, it is easily destroyed. Its resistance to heating or exposure to sunlight is very slight.

91.—Can medicines or drugs eradicate pullorum disease? No satisfactory medicine or drug has been found to be effective in eradicating or controlling the disease. Elimination of infected birds and proper follow-up measures must be resorted to in order to establish pullorum disease-free flocks.

92.—Is Massachusetts making progress in eradication of pullorum disease? In 1919 under the Poultry Disease Law, an organized testing program was started and since then the following testing results have been obtained.

Year	Flocks	Total Tests	Positive Tests Per cent	Non-Reacting Flocks
1920-21	108	24,718	12.50	25
1921-22	110	29,875	12.65	27
1922-23	121	33,602	7.60	29
1923-24	139	59,635	6.53	38
1924-25	156	66,503	2.94	79
1925-26	201	67,919	2.31	124
1926-27	249	127,327	4.03	114
1927-28	321	232,091	6.52*	138
1928-29	413	304,092	4.25*	228
1929-30	460	386,098	2.17	309
1930-31	447	402,983	1.47	328
1931-32	455	420,861	0.90	355

*Based on total birds tested: 1927-28, 190,658 birds; 1928-29, 254,512 birds.

The success in pullorum disease eradication in Massachusetts depends to a great extent upon the cooperation of the poultrymen. If Massachusetts poultrymen expect to improve the standing of their flocks in respect to pullorum disease, they must adopt and conscientiously follow sound eradication and preventive methods.

93.—Where may Massachusetts poultrymen obtain information regarding pullorum disease and testing service? Requests concerning pullorum disease and testing service should be forwarded to the Department of Veterinary Science, Massachusetts State College, Amherst, Mass.

Publication of this Document Approved by Commission on Administration and Finance
7M-6-32 No. 5728

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 285 JUNE, 1932

The Relation of Temperature to the Activity and Control of the Plum Curculio in Apples

By W. D. Whitcomb

The plum curculio frequently does more damage to apples in Massachusetts than all other insects together. As a result of the heavy loss to fruit growers, studies of the factors which influence the activity of this insect were conducted at Waltham. Early in the work temperature was found to play an important part in the problem of control, and the results of studies with this factor are here reported.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE RELATION OF TEMPERATURE TO THE ACTIVITY AND CONTROL OF THE PLUM CURCULIO IN APPLES

By W. D. Whitcomb
Assistant Research Professor of Entomology

INTRODUCTION

Although careful laboratory experiments (2, 9) have shown that lead arsenate and other standard stomach poisons are strongly toxic to the plum curculio[1], many fruit growers in Massachusetts have been unable to obtain satisfactory control of this insect on apples by using these insecticides. This condition led to an investigation of the factors which influence the activity of the plum curculio in the hope of finding a practical index for more accurate timing of spray or dust applications to combat this pest. Early in the work temperature was found to play an important part in the problem, and the results of studies with this factor are reported herein.

SUMMARY OF SEASONAL HISTORY AND HABITS

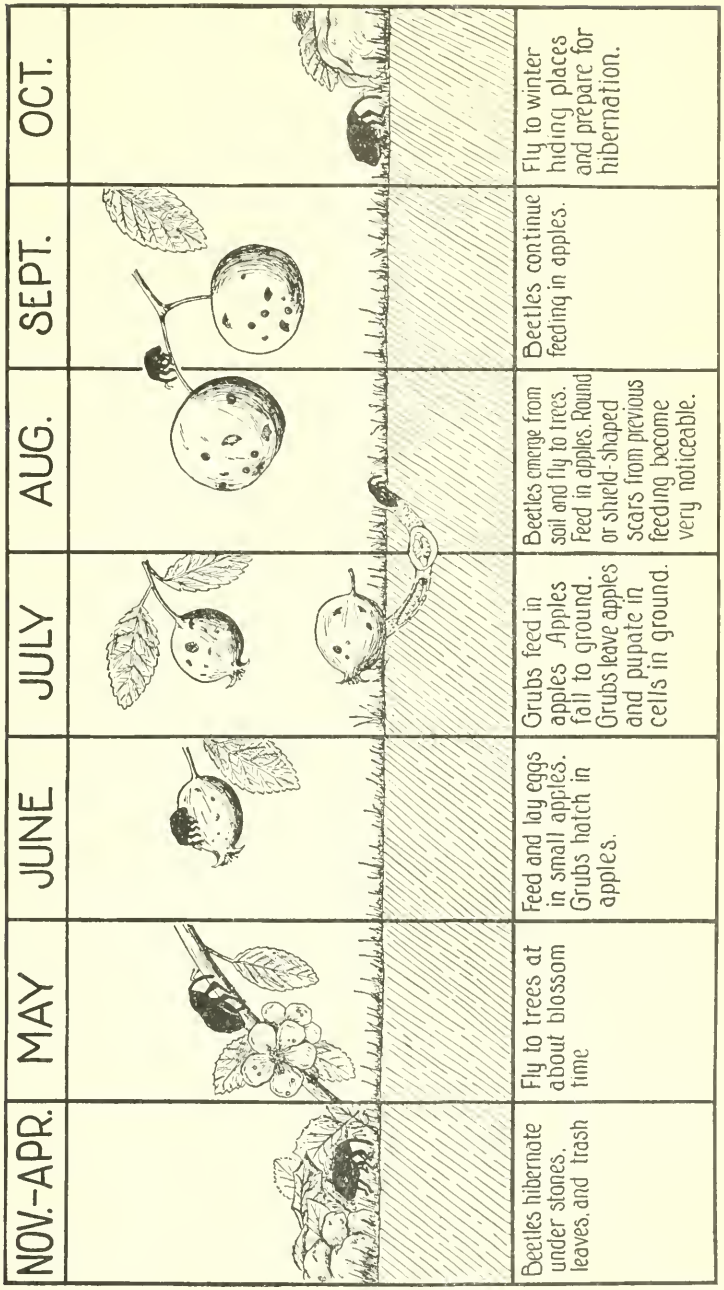
In order to connect the results of the experiments reported in this bulletin with the normal activities of the plum curculio, the seasonal history and habits of this insect are briefly summarized and a pictorial diagram is shown on the opposite page. A complete discussion of these activities is presented in Massachusetts Agricultural Experiment Station Bulletin 249.

After spending the winter under leaves and brush in the vicinity of the orchard, particularly around stone walls, the beetles leave their hibernating quarters with the approach of warm weather. The most adventurous of them appear about the time the blossom buds show pink, but it is usually a week after the petals have fallen before the majority of them are found in the trees. About half of these beetles are males and half are females. The first beetles feed slightly on the petals of the buds and blossoms but they eat very little until growing fruit is available. When the fruit is about half an inch in diameter, it provides abundant food and a suitable place for laying eggs, being most attractive to the beetles at this stage of development.

Both feeding punctures and egg punctures are made in the fruit. The former are small round holes extending into the flesh about one-eighth of an inch, while egg punctures are distinguished by a characteristic crescent-shaped cut which partially surrounds the sunken egg and relieves the pressure of the rapidly growing fruit. Insectary records in Massachusetts show that the beetles make an average of 118 feeding punctures and that an average of 176 eggs are laid during their normal life. The larvae or grubs hatch in about a week and immediately tunnel toward the center of the fruit, requiring about 16 days of feeding to become a full-grown grub. Almost without exception, an infested apple falls to the ground before the grub has finished feeding, and about a week later the grub leaves the apple to enter the ground where it forms a small earthen cell two or three inches below the surface. The insect spends about a month in the soil where it prepares for the resting period, performs the necessary transformations

[1] *Conotrachelus nenuphar* Herbst. Family Curculionidae. Order Coleoptera.

Figure 1.—The Seasonal History of the Plum Curculio in Apples in Massachusetts.



of pupal development and toughens its body for the hardships of adult life. These summer beetles emerge about August 1 and spend the remainder of the summer in the trees feeding moderately on the maturing fruit. With the approach of cold weather they seek shelter in which to pass the winter.

METHODS AND EQUIPMENT

All studies of the life history, seasonal history, and habits of the curculio under normal conditions were made in a screened open-air insectary measuring 15 x 25 feet. For most of the work, the insects were confined in glass battery jars 8 inches high and 6 inches in diameter, having 2½ inches of moist sand in the bottom. Glass vials imbedded in the sand supplied water to keep the fruit from wilting during the experiments. Observations were made daily. Records of temperature and relative humidity were secured from a hygrothermograph enclosed in a standard Weather Bureau kiosk. Plum curculios used in the studies were reared in the insectary or collected from infested apple trees early in the season by jarring the adult beetles onto cloth-covered frames. Beetles not under observation were held dormant in an ice chest maintained at 45° F.

In 1931, three constant-temperature cabinets became available. These cabinets are 36 x 36 inches square and 60 inches high, having a frame of oak and being enclosed on all sides by two panes of plate glass with an air space of 1½ inches between the panes. On one side is a door having a pressure slide latch. Refrigeration is supplied from two cooling coils suspended from the top of the cabinets, through which methyl chloride is forced by an electric motor-driven compressor. Heat is supplied at the bottom of the cabinet by a 24-inch electric strip heater which is connected with a small electric fan at the top providing circulation whenever the heater operates. Each temperature unit is connected with a mercury thermostat which insures automatic control. A constant temperature within 30 degrees of the outside temperature is guaranteed, and it has been operated successfully between 30° and 80° F. The usual variation from the desired temperature is about 3° F., since the mechanical equipment allows a deficiency of about 1½° F. above and below the set temperature before the controls operate. These cabinets were operated in a greenhouse entry having a cement floor and good ventilation. The glass roof was heavily whitewashed, and splitwood curtains provided additional shade from bright sun. No control of humidity was maintained in these cabinets, but frequent readings on psychrometric equipment showed 65 to 85 per cent relative humidity. In these experiments constant temperatures were maintained at 55°, 65° and 75° F., while a fourth constant of 85° F. was obtained in a 110-volt, 150-watt electric incubator having a glass door.

In these cabinets the beetles were confined in battery jars as in the insectary studies.

The spray solutions were applied to the apples in the laboratory through a mist nozzle delivering 12 gallons per hour under 30 pounds air pressure. The apparatus was similar to that used by Miller (5) in Ohio, except that the air pressure was supplied through an auxiliary pipe from a large compressor which was in operation in the building. With this equipment the amount of spray delivered was constant for any unit of time. The apples were thoroughly wet without dripping, and this usually required two complete turns with a separate wetting of the blossom and stem end. A supply of apples for a week was sprayed at one time and the stems of these apples were placed in water in a refrigerator until they were used.

REACTION OF FRUIT INSECTS TO TEMPERATURE

Studies of the relation of temperature to the development and activity of insects have been reported by several investigators, and among fruit insects the codling moth has received particular attention of this nature. It is well known that the female codling moth will lay few if any eggs when the temperature is below 60° F., while Glenn (3) and Shelford (7) have completed a long series of experiments showing the number of accumulated "hour degrees" above a certain "threshold temperature" that are necessary for the completion of each biological development in the codling moth. With these data they are able to predict in advance with considerable accuracy the reactions which climatic conditions will exert on the insect in the orchard. Later, Peterson and Haeussler (6) found that the oriental peach moth had temperature requirements similar to those reported for the codling moth by Glenn (3). The reactions of the plum curculio at controlled temperatures are not known to have been reported previously.

EFFECT OF TEMPERATURE ON THE PLUM CURCULIO

Development of Immature Stages

When confined at 55° F., all eggs, larvae, and pupae which were under observation failed to develop. Death appeared to be due to an excessive retardation of biologic development rather than to any sudden shock from low temperature. The eggs were observed in their natural location in punctures in small apples, and it was usually two or three times the normal incubation period before the egg collapsed and it could be definitely determined that it would not hatch. Mature larvae in soil began pupation but died before the distinguishing pupal characters developed.

At 65° F., development was completed, but the incubation of the egg and the period spent in the soil as mature larva, pupa, and adult were considerably longer than under normal outdoor conditions. The feeding period of the larva in the apple was about normal though slightly shorter than under outdoor conditions, and it appears that this stage of the insect is practically immune to reasonable variations in air temperature, or that the green apple provides good insulation.

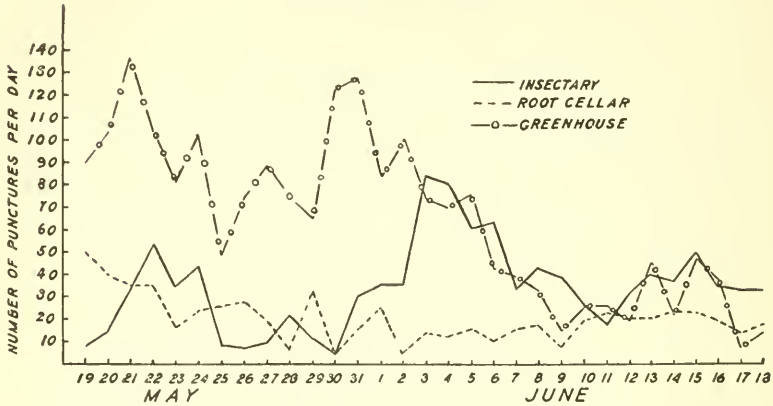
At 75° F., development was considerably more rapid than normal in all stages except the feeding period of the larvae in the apple. The greatest increase in rapidity of development occurred between 65° and 75° F., and 75° F. appears to be very near the optimum temperature for the development of the plum curculio. The change at 85° F. was so slight as to be insignificant and there was a slight retardation in the larval feeding period at the higher temperatures. A summary of this development is presented in Table I.

TABLE 1. DEVELOPMENT OF IMMATURE STAGES OF PLUM CURCULIO AT CONSTANT TEMPERATURES. WALTHAM, MASS., 1931

Temperature	Average Number of Days Required For:		
	Incubation of Egg	Feeding of Larva	Development of Larva, Pupa, and Adult in Soil
55° F.	Development not completed		
65° F.	11	13.75	37.75
75° F.	3.8	13.87	22.50
85° F.	3.08	15.00	21.85
Normal outdoor*	7.1	16.09	30.54

*Average of insectary records for three years.

Figure 2.—Number of Punctures Made in Apples by Twenty Plum Curculios when Confined at Low, Normal, and High Temperatures. Waltham, Mass., 1930



Activity of Beetles

Preliminary Experiments in 1930

The first experiments relating to the effect of temperature on the activity of the plum curculio were made in a root cellar, a greenhouse, and an open-air insectary. The temperature in the root cellar was always below 70° F. and represented moderately cool conditions, while that in the greenhouse was always above 70° F., reaching over 100° F. on warm, sunny days, and represented warm conditions. Records of the activity of 20 beetles were made daily from May 19 to June 18 which was the period of greatest normal activity. In the root cellar, each beetle made an average of 31.45 punctures; in the insectary, 59.55; and in the greenhouse, 99.55. As shown in Table 2, the total number of punctures at normal outdoor temperatures was approximately twice as many as under cool conditions, and one-half as many as at high temperatures. Figure 2 shows the daily fluctuation in activity which is in direct relation to the outside temperature, and this is reflected in the records for both the greenhouse and root cellar where the temperature was only partially controlled.

Table 2.—Activity of Twenty Plum Curculio Beetles Each at Low, Normal, and High Temperatures. Waltham, Mass., May 19 to June 18, 1930

Location	Condition	Temperature Range °F.	Number of Punctures		
			Egg	Feeding	Total
Root Cellar	Cool	58-70	88	541	629
Insectary	Normal Outdoor	35-94	279	912	1191
Greenhouse	Warm	70-105	375	1616	1991

Analysis of Insectary Records

An analysis of the insectary records for 1927 to 1930 inclusive shows that a similar stimulation in activity corresponding with the maximum daily temperature has been apparent throughout the life history studies. When the records of daily activity are grouped according to each ten degrees of maximum temperature (Table 3), there is a steady but variable gain in the number of punctures

per cage for each higher temperature group. Each cage contained 20 curculios and the records were taken during the height of the curculio activity in each season, both egg punctures and feeding punctures being recorded. Observations have indicated that the beetles are equally active when a maximum temperature of 80° F. follows a minimum of 40° F. and when it follows a minimum of 50° F., and it appears that maximum daily temperatures are as satisfactory as mean daily temperatures for comparing thermotropic activity of adult plum curculios.

TABLE 3.—ACTIVITY* OF PLUM CURCULIO BEETLES GROUPED ACCORDING TO MAXIMUM DAILY TEMPERATURE. WALTHAM, MASS., 1927-1930

Maximum Temperature ° F.	1930		1929		1928		1927		1927-1930	
	Days	Punctures	Days	Punctures	Days	Punctures	Days	Punctures	Days	Punctures
60 or below	5	9.2	0	...	2	12.0	1	8.0	8	9.75
61-70	5	22.4	2	43.0	5	26.0	9	36.5	21	31.26
71-80	10	33.1	12	51.3	13	30.1	14	48.9	49	41.27
81-90	6	46.0	10	69.9	10	38.4	7	62.4	33	54.42
Above 90	5	57.8	3	126.3	0	..	0	....	8	83.48

*Average daily punctures per cage of 20 beetles.

Experiments at Controlled Temperatures in 1931

In 1931 the activity of the plum curculio beetles was studied in the constant temperature cabinets which were operated at 55°, 65°, 75°, and 85° F. Two cages of 10 beetles each were maintained at each temperature, and records of the number of punctures in unsprayed fruit were made daily.

At 55° F. the beetles were very sluggish but not entirely dormant since they made an average of 1.025 punctures per day and laid a few eggs during the first 10 days when activity is greatest. At 65° F. activity was nearly normal but below the average for out-of-door conditions. The greatest number of punctures was made at 75° F., although this exceeded the record at 85° F. very little. The average of 6.675 punctures per beetle per day, as shown in Table 4, represents an increase of 277 per cent over this same activity at 65° F., and indicates that 75° F. is very near the optimum temperature for activity.

TABLE 4.—ACTIVITY* OF PLUM CURCULIO BEETLES FOR TEN DAYS AT CONSTANT TEMPERATURES. WALTHAM, MASS., 1931

Temperature	Average Number of Punctures		
	Egg	Feeding	Total
55° F.	.130	.895	1.025
65° F.	.445	1.960	2.405
75° F.	1.015	5.660	6.675
85° F.	1.035	5.020	6.055
Normal outdoor**	.210	2.405	2.615

*Average number of punctures per curculio per day
**Average of insectary records for 3 years.

THEORY OF RELATION OF TEMPERATURE TO TOXICITY OF STOMACH POISONS TO THE PLUM CURCULIO

When plum curculio beetles feed on fruit coated with lead arsenate or some other arsenical poison they take small particles of the poison, particularly the arsenic, into their stomach. The beetles may swallow the poison with their

food, or they may swallow it after it has stuck to their mouth parts while they are crawling over the fruit and foliage in search of a suitable place to feed. When feeding is greatly reduced, as it is by low temperatures, the small amount of arsenic obtained may act as a temporary stimulant rather than a toxin, and the result is not fatal until an accumulative poisoning is built up by continued small doses. At a constant temperature of 55° F., several beetles lived from 25 to 27 days with only poisoned fruit for food, while at 75° F. the maximum number of days that beetles lived on similar poisoned fruit was 7 to 10 days.

When high temperatures stimulate feeding and egg laying so that the beetles make several punctures per day, the greater amount of poison obtained from these several punctures causes death in a proportionately shorter time. In one experiment 10 beetles at 55° F. lived 10.6 days and made an average of 4.1 punctures each during their life; while another group at 65° F. averaged 4.2 punctures each but lived only 5.4 days because the punctures were made in a shorter period of time, and a much greater amount of poison was obtained before the natural resistance of the insect could overcome the toxic effect produced.

LABORATORY EXPERIMENTS WITH PLUM CURCULIO BEETLES FEEDING ON POISONED FRUIT AT CONTROLLED TEMPERATURES

Lead Arsenate at Different Concentrations

A summary of the records from 2 cages of 10 beetles each, confined in the constant temperature cabinets with fruit sprayed with lead arsenate showed that the average number of days which the beetles lived decreased consistently with each increase of 10 degrees in temperature from 55° F. to 85° F. The greatest decrease in length of life was between 55° F. and 65° F. Table 5 also shows that the average number of days which the beetles lived decreased consistently with the increase in concentration of lead arsenate from 3 pounds to 5 pounds in 100 gallons of water. However, the decrease in length of life in favor of 5 pounds of lead arsenate compared to that where 4 pounds was used is so little that it is doubtful if the slightly better control is worth the cost of an additional pound of poison. When lead arsenate was increased to 6 pounds in 100 gallons of water, the length of life of the beetles increased at three of the four temperatures over that when 5 pounds of lead arsenate in 100 gallons of water were used. This may indicate that concentrations of lead arsenate greater than 5 pounds in 100 gallons became repellent to the plum curculio, and they may live longer when feeding on fruit sprayed with 6 pounds of lead arsenate in 100 gallons of water, because they do not feed on such fruit as quickly or as readily. Similar action has been reported by Stellwaag (8) in Germany who found materials with 15 per cent arsenate more repellent and consequently less effective against silkworms than those containing 10 per cent of this poison, and by Crumb (1) who states that in experiments with poisoned bran baits, "a dosage of 1 pound of Paris Green to 24 pounds of bran is rather repellent to cutworms, while a bait with half this concentration of poison is scarcely at all repellent."

Lead Arsenate Plus Other Materials

With 4 pounds of lead arsenate and 1 pint of fish oil in 100 gallons of spray, the average life of the beetles was only slightly less than where fish oil was not used, indicating that the fish oil has little, if any, repellent or insecticidal action against the plum curculio. However, fish oil is an excellent agent for spreading and sticking the lead arsenate in an even film over the fruit and for preventing the poison from weathering and washing off too rapidly.

TABLE 5.—AVERAGE LIFE OF PLUM CURCULIO BEETLES FEEDING ON POISONED FRUIT. WALTHAM, MASS., 1931

Insecticide	Average Number of Days Alive			
	At 55° F.	At 65° F.	At 75° F.	At 85° F.
Lead arsenate 3 lbs.-100	13.5	8.4	5.55	4.0
Lead arsenate 4 lbs.-100	10.7	6.4	5.0	3.1
Lead arsenate 5 lbs.-100	9.6	5.4	4.75	3.0
Lead arsenate 6 lbs.-100	14.7	5.5	4.15	3.4
Check	62.65	76.85	59.1	26.1

When concentrated lime-sulfur solution at the rate of 2 gallons in 100 gallons, and chemical hydrated lime at the rate of 10 pounds in 100 gallons, were added to the lead arsenate-fish oil mixture, the beetles lived slightly longer at the two lower temperatures, indicating some repellent action under these conditions. At the higher temperature, however, this mixture appeared more efficient than the lead arsenate alone or with fish oil, which seems to indicate that when a fungicide is needed in a spray especially applied for combating the plum curculio, lime-sulfur and chemical hydrated lime can be added without seriously reducing the insecticidal value of the mixture. A summary of these records is given in Table 6.

TABLE 6.—AVERAGE LIFE OF PLUM CURCULIO BEETLES FEEDING ON FRUIT POISONED WITH DIFFERENT SPRAY MIXTURES. WALTHAM, MASS., 1931

Insecticide	Average Number of Days Alive			
	At 55° F.	At 65° F.	At 75° F.	At 85° F.
Lead arsenate 4 lbs.-100	10.7	6.5	5.0	3.1
Lead arsenate 4 lbs.-100 Fish oil 1 pint	10.6	5.45	4.9	3.9
Lead arsenate 4 lbs.-100 Lime-sulfur 2 gallons Chemical hydrated lime 10 lbs. Fish oil 1 pint	12.4	7.0	4.45	2.85

RELATION OF TEMPERATURE TO THE CONTROL OF THE PLUM CURCULIO IN THE ORCHARD

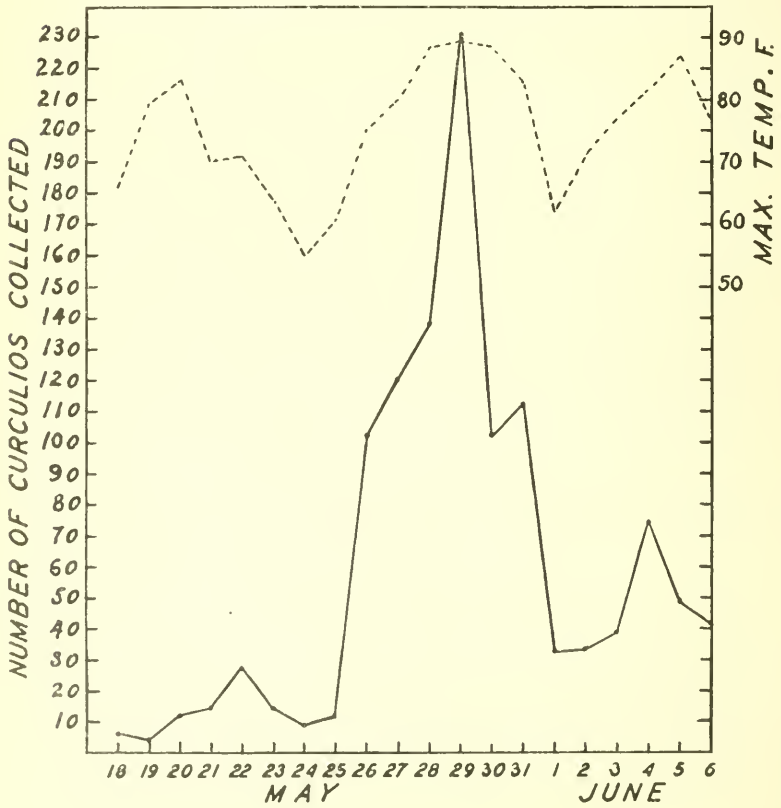
Suggestions for Spraying

In Massachusetts the climate is very variable during May and June, frequently changing from periods of cold wind and rain to periods of abnormally high temperatures. These climatic irregularities govern the activities of the plum curculio and other pests in the orchard in much the same way as shown by this study of their response to artificially maintained temperatures, and place a premium on the timeliness of the application of control measures. Newly applied sprays are more effective during periods of maximum curculio activity than are older spray residues. It would seem that the coating of poison, especially

when its adhesiveness is aided by a spreader or sticker, would persist in its maximum efficiency for several days, but experiments (4) have shown that the surface area of the apple increases 6 per cent or more per day during this period of growth, with a proportionate increase in the unprotected area of fruit. It is, therefore, possible for about one-third of the surface of the apple to be free from poison 5 days after spraying, and the curculio beetles are quick to take advantage of these unpoisoned areas on the young fruit. The physical force of the spray when applied causes the curculio beetles to fall from the tree as is their habit when disturbed in any way, and apparently it is more difficult for them to find an unpoisoned area on the apple when they return to a recently sprayed tree.

Where there may be some delay in treating the complete orchard, it is advisable to spray first that part of it which is adjacent to woods, stone walls and brush, or other suitable winter cover where the beetles will congregate first. It is also advisable during periods of maximum activity to spray first those varieties which are most susceptible to curculio injury. Previous experiments (9) have shown that apple varieties which bloom earliest and grow most rapidly immediately after petal fall are the first to provide suitable locations for feeding and

Figure 3.—Occurrence of Overwintering Plum Curculios in the Trees in Relation to Maximum Daily Temperature. Waltham, Mass., 1931



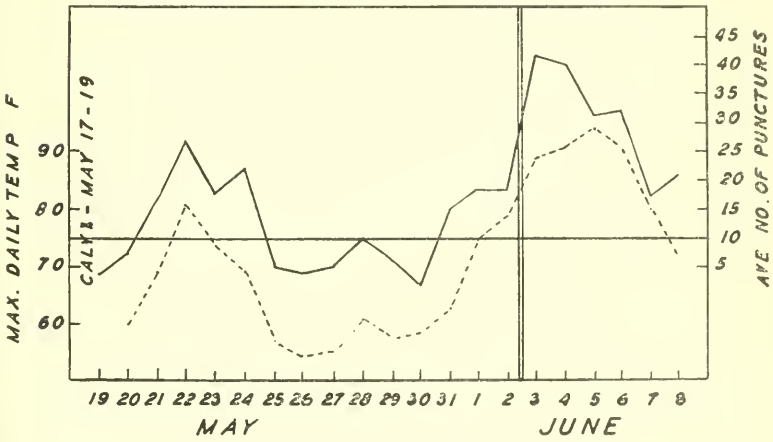
depositing eggs, and, therefore, are subjected to curculio attack earlier and over a longer period. In Massachusetts, Duchess, Gravenstein, and Baldwin are very susceptible, while McIntosh is the least susceptible of the common commercial varieties.

Appearance of Hibernating Curculios in the Trees

High temperatures which stimulate feeding and oviposition by the curculio beetles also hasten the rapidity with which they leave their winter cover and congregate in the trees.

In seasons such as 1931 (Figure 3) when a period of warm weather comes soon after the petal-fall stage, the greatest population of curculios in the trees, as well as the greatest activity of the beetles, occurred in the same period, making the prompt application of control measures doubly imperative. It may happen, however, that moderately high temperatures have caused a large number of beetles to enter the trees without inducing excessive activity or injury to the fruit, and this condition is followed by a period of cool weather with the maximum temperatures usually below 60° F., which greatly decreases the activity of the beetles. In this case the presence of the beetles in the trees is relatively unimportant, except that the control treatments must be applied promptly with the approach of maximum temperatures above 75° F. Such a condition was approached in 1930 as indicated in Figure 4.

Figure 4.—Relation of Maximum Daily Temperatures to the Activity of the Beetles During the Critical Period for Control of the Plum Curculio. Waltham, Mass., 1930



——— Average number of punctures per day by 10 beetles in insectary.
..... Average maximum daily temperature in insectary.

Climatic Conditions Influencing Control in 1930

In 1930, the climatic conditions immediately following the petal fall of apples represented well defined extremes, as shown in Figure 4. The calyx spray was applied from May 17 to 19, and was followed by two days of cool weather. On May 22, the maximum temperature jumped to 81° F., and reached 74° F. on

the following day. There was some curculio activity. This was followed by eight days of cool, rainy weather with maximum temperatures below 70° F., which reduced curculio activity to a minimum. The warm weather of May 22 and 23 promised to be the beginning of a period of great curculio activity, but the duration of the high temperatures was so short that comparatively little feeding took place in the orchard. On June 1 the maximum temperature was 75° F., and it continued above 80° F. for seven days, with a maximum of 94° F. on June 5. The majority of the curculio activity took place in that period. Because of the long period of unfavorable weather preceding, the majority of the fruit growers sprayed during the early part of the warm period from June 1 to 8, and the best control of this pest in recent years was obtained.

Figure 4 also shows that the critical period in curculio activity, in respect to high temperature, did not occur in 1930 until June 1 to 8, 12 to 14 days after the calyx application. Although there was little curculio activity during the cool weather from May 19 to June 1, there was a gradual accumulation of curculios in the trees and these were stimulated to considerable activity by the first high temperatures. Therefore, the dividing line between timely control treatments and late treatments was June 2.

Orchard Control in Relation to Time of Application

The practical application of these temperature studies is evident in an analysis of the records of blemishes on harvested fruit taken by Mr. Fred E. Cole of the Worcester County Extension Service, and Mr. John C. Handy of the Middlesex County Extension Service, in connection with their County Fruit Pest Survey, and the State 90 Per Cent Clean Apple Club Project. These orchards had a crop of at least 300 bushels of one variety, and the spray was carefully applied from a commerical standpoint. The materials used were approximately the same in each case, and with few theoretical exceptions the difference in control is due to the time of application.

Worcester County, 1930

In 1930, the Worcester County records for 29 orchards show that 11 per cent better control of the plum curculio on McIntosh apples, and 14 per cent better control on Baldwin apples, were obtained by spraying from May 28 to June 2, than when the spray application was made later. No sprays were applied on May 30 and 31 because of unfavorable weather, and these dates are omitted in Table 7.

Table 7.—Percentage of Harvested Apples Injured by Plum Curculio. Worcester County, Mass., 1930

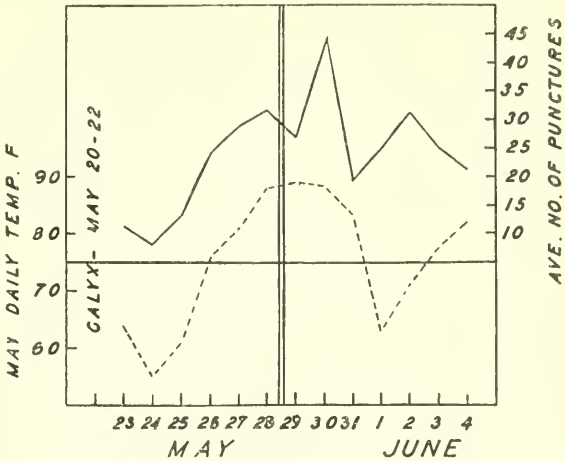
Time of Application	Variety	Number of Orchards	Infestation, Per Cent		
			Maximum	Minimum	Average
May 28, 29, June 1, 2	McIntosh	10	10.0	0.47	3.79
	Baldwin	4	4.9	1.7	3.55
June 3, 4, 5, 6, 7	McIntosh	7	64.5	0.36	14.82
	Baldwin	8	34.6	4.2	17.28

Climatic Conditions Influencing Control in 1931

In 1931 the critical period in curculio activity in respect to temperature came 4 to 6 days after the calyx spray was applied in most orchards, and extended

from May 26 to June 1. Very few curculios were in the trees before this time (Figure 3), and the dividing line between effective and late control treatments was May 28, as is indicated by the double line in Figure 5.

Figure 5.—Relation of Maximum Daily Temperatures to the Activity of the Beetles During the Critical Period for Control of the Plum Curculio. Waltham, Mass., 1931



——— Average number of punctures per day by 10 beetles in insectary.
Average maximum daily temperature in insectary.

Worcester County, 1931

The 1931 records from 38 orchards in Worcester County showed 20 per cent better control in Baldwin orchards and 14 per cent better control in McIntosh orchards where the application was made on May 26, 27 or 28 than where the sprays were applied after this date. It is interesting to note that with both varieties of fruit the minimum infestation in orchards receiving a late application is greater than the maximum infestation where a timely application was made.

TABLE 8.—PERCENTAGE OF HARVESTED FRUIT INJURED BY PLUM CURCULIO. WORCESTER COUNTY, MASS., 1931

Time of Application	Variety	Number of Orchards	Infestation, Per Cent		
			Maximum	Minimum	Average
May 26, 27, 28	Baldwin	6	6.8	0.7	4.33
	McIntosh	6	4.2	1.2	3.0
May 29 to June 6	Baldwin	16	57.6	12.6	24.85
	McIntosh	10	39.7	7.3	17.88

Middlesex County, 1931

Similar records from 30 orchards in Middlesex County in 1931 showed a gain of 14 per cent control in orchards sprayed on May 26, 27, or 28, compared to those receiving later applications. No distinction between varieties is made in these orchards, and there is considerable variation due, apparently, to location and inconsistent thoroughness of application.

Table 9.—Percentage of Harvested Fruit Injured by Plum Curculio. Middlesex County, 1931

Time of Application	Number of Orchards	Infestation, Per Cent		
		Maximum	Minimum	Average
May 26, 27, 28....	12	16.0	0.8	6.56
May 29 to June 6	18	70.0	1.3	20.05

USE OF DUST FOR CONTROL OF PLUM CURCULIO

Laboratory experiments have shown that a dust containing 15 per cent of lead arsenate has compared very favorably with liquid sprays of lead arsenate.

In 1931, a block of trees in the orchard of Mr. George A. Drew, Westford, Massachusetts, was dusted with 85-15 sulfur-lead arsenate dust, while another block was sprayed with the recommended formula of lead arsenate 4 pounds, lime-sulfur solution 1 1-3 gallons, hydrated lime 10 pounds, fish oil 1 pint, water 100 gallons. The special curculio application was made to each block on May 29, and a second application was made on June 15. All apples from the June drop to harvest on 12 trees were examined for curculio injury. Gravenstein was the main variety in each block. The fillers in the sprayed block were Astrachan, and in the dusted block, Wealthy. More than 42,000 apples were examined, and the percentage of all fruit injured by curculio was 5.74 in the sprayed block and 6.12 in the dusted block. The difference between the treatments was also less than 1 per cent in the harvest fruit of all varieties, as well as in the Gravenstein harvest fruit. This seems to indicate that under conditions which prevailed in 1931 dusting was practically as effective as spraying, and gave satisfactory control when applied in this orchard. A summary of these records is given in Table 10.

Table 10.—Comparison of Spraying and Dusting for Control of the Plum Curculio in Apples. Westford, Mass., 1931

	Dusted Block		Sprayed Block	
	Apples examined	Fruit injured	Apples examined	Fruit injured
	Number	*Per cent*	*Number*	*Per cent*
GRAVENSTEIN				
Drops	4778	14.31	1965	16.58
Harvest	6673	5.93	4636	5.13
Total	11451	9.43	6601	8.54
WEALTHY				
Drops	6857	3.10	.....	.....
Harvest	4939	2.63	.....	.....
Total	11796	2.93	.....	.....
ASTRACHAN				
Drops		...	4688	6.54
Harvest		...	7904	2.93
Total		...	12592	4.28
BLOCK TOTAL	23247	6.12	19193	5.74

RECOMMENDATIONS

In many states the recommendations for combating the plum curculio on apples with insecticides are to spray or dust from 7 to 10 days after the petal-fall stage, and in many seasons applications at this time are timely. However, the experiments reported herein, together with observations during the past six years, indicate that the stimulation in activity by high maximum temperature is an important factor in determining the most timely application of insecticides.

Therefore the recommendations for combating the plum curculio on apples in Massachusetts are:

After the blossom petals have fallen, apply a special spray or dust in the first period of warm weather when the maximum temperature reaches 75° F. or higher and such temperatures promise to continue for 2 or more successive days. Use 4 or 5 pounds of lead arsenate in 100 gallons of spray, preferably with the addition of 1 pint of fish oil or linseed oil as a spreader and sticker. Except in severe infestations, 85-15 sulfur-lead arsenate dust can be substituted for the spray. When there are two distinct periods of high temperature within 15 days after the proper time for the calyx spray, apply a spray or dust in each period, using the same materials, and determining the time of application by the same temperature requirements as before. On scab susceptible varieties, or where the addition of a fungicide is desirable for any reason, liquid lime-sulfur or a similar material can be added to the spray without danger of greatly decreasing the efficiency of the mixture for combating the plum curculio.

SUMMARY

Studies of the plum curculio at controlled temperatures of 55°, 65°, 75° and 85°F. indicated that 75° F. is very near the optimum temperature for the development of the immature stages and the activity of the adults of this insect.

At 55° F. development of the immature stages was not completed, and at 85° F. development was practically the same as at 75° F.

Adults feed little and lay few eggs at 55° F., but make an average of 6.675 punctures per beetle per day when confined at 75° F. during the height of their activity.

The number of days which plum curculio beetles lived when feeding on poisoned fruit decreased with each increase of 10 degrees in temperature from 55° to 85° F., and each increase in the concentration of lead arsenate from 3 to 4 to 5 pounds in 100 gallons of water.

Lead arsenate at the rate of 6 pounds in 100 gallons of water is apparently repellent to the plum curculio.

Five pounds in 100 gallons of water appears to be the most effective concentration of lead arsenate although its advantage over 4 pounds in 100 gallons is small.

The addition of fish oil to lead arsenate results in a slight increase in effectiveness, and its use is recommended especially to aid the sticking and spreading of the spray to the fruit and foliage.

The addition of lime-sulfur and chemical hydrated lime to lead arsenate-fish oil does not decrease the effectiveness of the combination at high temperatures.

The variable temperature in Massachusetts has a noticeable influence on the activity of the plum curculio, and spray applications should be timed according to the temperature. (See Recommendations.)

The critical period in the control of the plum curculio in apples in Massachusetts occurs during the first warm weather after the blossom petals have fallen when the maximum temperature remains above 75° F. for two or more days.

High temperatures about the time when apple trees are in bloom cause the plum curculio beetles to enter the trees in large numbers.

In 1930, the critical period for control occurred from June 1 to 5, 12 to 14 days after the calyx spray was applied, and records from 29 orchards in Worcester County showed 11 per cent better control on McIntosh and 14 per cent better control on Baldwin where sprays were applied just before or during the early part of the critical period.

In 1931, the critical period occurred from May 26 to June 1, 4 to 6 days after the calyx application. In Worcester County, timely sprays during the early part of the critical period gave 20 per cent better control on Baldwins and 14 per cent on McIntosh than later applications. Similar results were secured in 30 orchards in Middlesex County.

In 1931, a timely application of 85-15 sulfur-lead arsenate dust controlled the plum curculio in Gravenstein apples almost as well as a spray of lead arsenate and fish oil, the difference in favor of the spray being 0.89 per cent.

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Publication of this Document Approved by Commission on Administration and Finance
6M-7-'32. No. 5816.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 286 JUNE, 1932

Types of Intensity In Rhode Island Reds

By F. A. Hays and Ruby Sanborn

Intensity or rate of laying is one of the very important inherited characters affecting annual egg production in poultry. Various methods have been used for measuring intensity, and there is an increasing need for more information concerning the relative merits of the different measures as well as for definite data concerning the relation of intensity to other traits affecting fecundity. Interrelations between the rate of laying in three different seasons and the relative values of six short-time measures of intensity are considered in this report.

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TYPES OF INTENSITY IN RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry, and
Ruby Sanborn, Research Assistant in Poultry Husbandry

INTRODUCTION

Intensity or rate of laying is recognized as of vital importance in breeding for high fecundity. Various methods have been used for measuring intensity, and there is an increasing need for more information concerning the relative merits of the different measures as well as for definite data concerning the relation of intensity to other traits affecting fecundity.

Hurst (1921) measured intensity on a percentage basis during three periods into which he divided the pullet laying year. He called the period from first pullet egg to March first, the winter period; that from March first to July first, the spring period; and that from July first to the end of the laying year, the autumn period. By dividing the number of eggs laid in a period by the days making up the period, he obtained the intensity on a percentage basis. He states that the annual egg record depends upon high intensity during these three periods, and places the dividing line between genetic high and low intensity at 30 per cent. This worker does not report upon the relative importance of the three periods or upon their possible relation to each other.

Dryden (1921) used the two highest months in the pullet year as a measure of intensity. He found it possible to increase annual production by selection on this basis.

Goodale and Sanborn (1922) offer as measures of intensity the egg records of individual months, the production in the initial cycle, and the production during the inter-broody periods. No attempt is made, however, to discover their relative importance. Harris and Goodale (1922) studied the correlation between individual monthly production and production for the remainder of the year in Rhode Island Reds. Their data indicate that production during January shows the most intimate correlation.

Hays and Sanborn (1927) report the correlation between four measures of intensity and annual egg production. These data show the following values for r: first 60 days vs. remainder of the year, $+.3082 \pm .0121$; mean winter clutch size vs. annual record, $+.3544 \pm .0117$; net winter rate vs. annual record, $+.4769 \pm .0104$; and annual rate vs. annual record, $+.7106 \pm .0066$. These writers conclude that mean winter clutch size is the most specific measure of intensity considered.

This report is concerned with clutch size in periods throughout the year as a measure of intensity. Data are presented to show the correlation between mean winter and mean spring clutch size, between mean winter and mean summer clutch size, and between mean spring and mean summer clutch size. The relation of clutch size during these three periods to four heritable characteristics affecting fecundity is shown by means of the coefficient of correlation. The mean clutch size during the individual months of March, April and May is also shown in relation to the four heritable traits. Finally, the correlations between mean clutch size during six intervals of time and annual production are presented.

Character of Birds Used

All Rhode Island Red pullets hatched during the five hatching seasons of 1925 to 1929 are included in these studies if their egg records appeared to be normal. These birds were carried in a number of different projects as follows: non-broody, high fecundity, egg size, variability in production, and intensity in relation to feather pigmentation. The number of individual birds concerned is 1695, except for those reported in Technical Bulletin 11, where the number is 2560 in studies concerned with mean winter clutch size.

In calculating the correlations, the entire range in age at first egg is included, only individuals exhibiting a pause of four days or more are included in the pause population, only individuals going broody during the pullet year are used in the broody studies, and the entire range is included in the persistency studies. All regressions are tested for linearity by Blakeman's (1905) test. Pearson's (1911) correction for the correlation ratio did not significantly alter the size of this constant in these data and is therefore not used.

A. INTERRELATIONS BETWEEN CLUTCH SIZE

Whether or not the appearance of high intensity in a bird during a particular period is a good criterion that such a bird is likely to be an intense layer in other periods of the year may be shown best by means of the coefficient of correlation. Consideration will be given to the following relations: Correlation between winter and spring clutch, correlation between winter and summer clutch and correlation between spring and summer clutch.

1. *Correlation Between Winter and Spring Clutch Size.*

The mean winter clutch is obtained by dividing the number of eggs from first pullet egg to the end of February by the number of clutches represented. Mean spring clutch is calculated by dividing the total eggs laid during March, April and May by the number of clutches concerned. Class intervals of one were used, and the mean winter clutch size of each individual was paired against her mean spring clutch. This was done for 1695 individuals to obtain the following constants:

Number of birds	1695
Mean winter clutch	3.35
Winter clutch standard deviation	±1.60
Mean spring clutch	4.07
Spring clutch standard deviation	±2.21
Coefficient of correlation	+.3854.±0139
Correlation ratio	.4171

The above constants show that although the mean spring clutch size was greater than the mean winter clutch size, the standard deviation for spring clutch shows it to be more variable than winter clutch. This fact may be genetically significant since the spring season is the normal period of laying in unimproved stock.

The regression of spring clutch size vs. winter clutch size is not strictly linear as shown by Blakeman's test. The correlation ratio, therefore, expresses the true relation and amounts to .4171. Using the squared value of the correlation ratio as a criterion of relationship as Ezekiel (1929) has suggested for the

correlation coefficient, the value .1740 appears. The interpretation is that about 17 per cent of the variability in spring clutch size may be accounted for as due to variability in winter clutch size. Such an association is certainly genetically significant though not very intimate.

2. *Correlation Between Winter and Summer Clutch Size.*

Mean summer clutch size represents the constant obtained by dividing the number of eggs laid from June first to the end of the 365-day laying year by the number of clutches involved. Records are available on 1682 birds, and winter clutch was paired against summer clutch for each bird with class intervals of one. The calculations show the following constants:

Number of birds	1682
Mean winter clutch	3.35
Winter clutch standard deviation	±1.60
Mean summer clutch	3.04
Summer clutch standard deviation	±1.60
Coefficient of correlation	+.2829±.0151
Correlation ratio	.3091

Mean clutch size during the winter months is somewhat greater than during summer. The variability in summer clutch size is also greater than for winter clutch size. The lesser variability in size of clutch during winter shows that the flock is more uniform in winter than in summer production.

Regression of summer clutch size on winter clutch size is not strictly linear by Blakeman's test. The correlation ratio is therefore used to measure the association. The constant +.3091 expresses a less intimate association between winter clutch size and summer clutch size than was observed between winter clutch and spring clutch with a constant +.4171. The squared value of .3091 is .0955 showing that about 10 per cent of the variance in summer clutch size may be associated with variance in winter clutch. Winter clutch size may be said to have a value for selection purposes of about 10 per cent as affecting summer clutch size.

3. *Correlation Between Spring and Summer Clutch Size.*

The spring period of March, April and May is the normal laying period for the unimproved domestic hen. Flocks bred for high fecundity differ greatly from unimproved flocks in the distribution of egg laying during the pullet year. For example, the Massachusetts Agricultural Experiment Station flock hatched in 1913 laid about 29 per cent of the yearly average by the end of February. The flock hatched in 1930 averaged to lay about 36 per cent of its eggs before March first. Moreover, the actual mean length of the productive year has increased from about 240 days to 340 days. These changes have reduced the proportion of total eggs laid during the spring season and this section is chiefly concerned with possible inter-relations of intensity, between the spring and summer periods.

The coefficient of correlation between mean spring clutch and mean summer clutch was calculated on 1682 birds to discover if there is a significant association. The constants are presented below:

Number of birds	1682
Mean spring clutch	4.08
Spring clutch standard deviation	±2.21
Mean summer clutch	3.04
Summer clutch standard deviation	±1.60
Coefficient of correlation	+.4593±.0130

Summer clutch shows the same coefficient of variation as spring clutch—about 53 per cent, compared with about 48 per cent for winter clutch. The fact should be observed, however, that the actual range in clutch size is ±1.60 both during the winter and summer periods and ±2.21 during the spring season.

Regression of summer clutch size on spring clutch size is linear by Blakeman's test. The magnitude of the correlation coefficient is greater than those shown in sections 1 and 2. Squaring r, the value .2110 appears which means that 21 per cent of the variance in summer clutch size is associated with variance in spring clutch size.

The data in sections 1, 2 and 3 on the inter-relationships of clutch size during the winter, spring and summer periods show significant correlations, yet the correlation is in no case sufficiently intimate to justify the use of clutch size in any one period as an accurate measure of intensity for the year. Hurst (1921 loc. cit.) made use of intensity throughout the year in his study of the genetics of egg production, and Hays and Sanborn (1927, loc. cit.) state that annual intensity should be adequately stressed in breeding for fecundity.

B. SHORT-TIME MEASURES OF INTENSITY IN RELATION TO FECUNDITY TRAITS

Table 1 is presented to set forth the correlation between six short-time measures of intensity and four characteristics affecting annual egg production and the correlation between each measure and annual egg record.

Winter Clutch Size

The coefficient of correlation between mean winter clutch and age at first egg is −.2273±.0103. Regression of winter clutch size on age at first egg is strictly non-linear according to Blakeman's test. Therefore, the correlation ratio of .7475 expresses the true relation between these two characters. Squaring the constant .7475 gives .5588 which indicates that about 56 per cent of the variance in winter clutch size is due to variance in age at sexual maturity. In other words, the data show that early sexual maturity is intimately associated with large winter clutch size.

Winter clutch size shows a non-linear relation to length of winter pause. The correlation ratio shows, however, that the two are actually correlated. The constant is .1297 indicating by its squared value of .0168 that about 2 per cent of the variability in winter clutch size is due to variability in pause duration.

The degree of broodiness measured by the number of days spent without production while broody during the pullet year is associated with large winter clutch size. There is a positive correlation constant of .2205±.0186. The regression is non-linear and the correlation ratio is .2548. Hays and Sanborn (1927 loc. cit.) have already shown that the mean winter clutch size is greater in broody than in non-broody birds.

Table 1.—Correlations Between Intensity and Inherited Characters Affecting Fecundity; also Between Intensity and Annual Egg Production.

	Winter Clutch (First egg to March 1)	Spring Clutch (March, April, May)	March Clutch	April Clutch	May Clutch	Summer Clutch (June to end of laying year)
Age at First Egg:						
Correlation Coefficient	−.2273 ± .0103	+.0322 ± .0164	+.0366 ± .0164	−.0106 ± .0164	+.0035 ± .0165	−.0481 ± .0164
Correlation Ratio	.7475					
Winter Pause, Days:						
Correlation Coefficient	−.0674 ± .0145	+.0729 ± .0197	−.0352 ± .0199	+.0052 ± .0199	+.0351 ± .0199	+.1112 ± .0197
Correlation Ratio	.1297	.3596				.1678
Total Broody Days:						
Correlation Coefficient	+.2205 ± .0186	+.0025 ± .0361	+.0234 ± .0363	−.0197 ± .0361	+.0386 ± .0361	+.2627 ± .0336
Correlation Ratio	.2548					.3531
Persistency:						
Correlation Coefficient	+.1692 ± .0130	+.1529 ± .0160	+.0673 ± .0163	+.1155 ± .0162	+.1122 ± .0163	+.1640 ± .0160
Correlation Ratio	.1927					.2078
Annual Production:						
Correlation Coefficient	+.3544 ± .0117	+.4559 ± .0130	+.2824 ± .0151	+.3268 ± .0147	+.3198 ± .0148	+.3958 ± .0139
Correlation Ratio	.4214	.5024	.3023	.3975	.3498	.4238

Persistency is associated with winter clutch size in a positive manner and regression is not linear. The coefficient of correlation is $+.1692 \pm .0130$ and the correlation ratio is .1927. The latter constant squared gives .0371 as the amount of variance in persistency associated with variance in winter clutch size.

Spring Clutch Size

Since the spring season of March, April and May may be considered the normal laying period in the Temperate Zone, it is important to discover if the intensity of laying at this time is associated with any of the four other characters affecting egg yield.

Table 1 shows that the correlation between age at first egg and mean spring clutch is negligible. In other words, the age at which the pullet begins to lay shows no relation to her spring intensity. The relation is linear, however.

The regression of spring clutch size on winter pause duration is distinctly non-linear by Blakeman's test. The correlation ratio shows that there is a positive relation amounting to .3596. Using the squared value of .3596 the constant .1293 is obtained, showing the percentage of associated variability between length of winter pause and size of spring clutch in 1156 birds with winter pause. This association between duration of pause and subsequent rate of laying is considered later in this report in connection with total days broody and summer rate of laying.

Total days broody during the pullet laying year is independent of spring clutch size in Table 1. This appears in contrast to the significant positive correlation between total days broody and mean winter clutch, already considered.

Table 1 shows a linear correlation between spring clutch and persistency of $+.1539 \pm .0160$. This supplements the observation reported by Hays and Sanborn (1926) that intense winter layers are more likely to be persistent layers.

Mean spring clutch size is independent of age at sexual maturity. The relation of spring clutch size to winter pause duration is fairly intimate though non-linear. The degree of broodiness measured by non-productive broody periods is independent of spring clutch size. The regression of persistency on spring clutch size is linear and of some significance.

March Clutch Size

The usefulness of a short-time measure of intensity is clearly evident provided such a measure accurately depicts the intensity for a long period. Mean clutch size during March may be considered as a possibility.

Table 1 shows no correlation between March clutch size and age at first egg, duration of winter pause, total days broody in the broody population or annual persistency. Clearly the rate of laying in March is independent of the four inherited characters just mentioned. The regression of March clutch size on the four above-mentioned characters is strictly linear by Blakeman's test.

April Clutch Size

The correlation coefficient indicates complete independence between mean clutch size during the month of April and age at first egg, duration of winter pause and total days broody. The regression is strictly linear in all cases.

The correlation between April clutch size and annual persistency is of low degree and the regression is linear. The amount of variance in April clutch size

associated with variance in persistency is only .0133 and is far too small to be of significance. These data, therefore, point to no association between the four inherited traits considered and April clutch size.

May Clutch Size

Table 1 shows no significant correlation between May clutch size and the three inherited characters, age at first egg, winter pause duration and total days broody. The correlation coefficient of $+.1122 \pm .0163$ between May clutch size and persistency is of very small magnitude and of little significance. Blakeman's test shows that the relation between May clutch size and the four inherited traits is linear. The general statement seems justified; that clutch size during the three spring months is practically independent of the four inherited characters considered essential to high annual egg production.

Summer Clutch Size

The period from June first to the end of the 365-day laying year is often a period of low production in improved flocks. During this time mortality is likely to be high, many birds may stop laying because of broodiness, others lay at a low rate and still others do not persist in laying to the end of their year. Information regarding the possible relation of clutch size at this season to inherited fecundity traits should be of considerable value.

Table 1 indicates by means of the insignificant value of r, that age at first egg and summer clutch size are independent. The same relation has already been indicated between age at first egg and spring clutch in contrast to a significant value of $-.7475$ between age at first egg and winter clutch size.

There is a small non-linear correlation between duration of winter pause and summer clutch size. The value of the constant is $+.1678$ indicating to a small degree the tendency for a long winter pause to enable the bird to lay at a slightly higher rate in summer.

Regression of days broody on size of summer clutch is non-linear and positive. The correlation ratio .3531 gives the true relation. This value is of considerable significance and indicates that the inter-broody periods tend to be periods of heavy laying. This agrees with the previous observation that winter pause duration is correlated with size of spring clutch. These data indicate that a period of non-production is likely to be followed by large clutches.

Persistency does not show a linear regression on summer clutch size. Using the correlation ratio to express the correlation, the positive value .2078 is obtained. Such a constant shows that intense layers tend to a small degree to be persistent layers.

In general, the study of the relations of six short-time measures of intensity to inherited characters affecting fecundity shows the following significant correlations: Winter clutch and early sexual maturity, spring clutch and duration of winter pause, summer clutch and duration of winter pause, winter clutch and days broody, summer clutch and days broody, winter clutch and persistency, spring clutch and persistency and summer clutch and persistency.

C. SHORT-TIME MEASURES OF INTENSITY IN RELATION TO ANNUAL EGG PRODUCTION

Table 1 also includes the correlation coefficients showing the relation between six measures of intensity and annual egg records.

The regression of annual egg production on winter clutch size is distinctly non-linear by Blakeman's test. The correlation ratio with a value of .4214 supplies a true measure of association. The magnitude of this constant squared is .1776 showing that 18 per cent of the variance in annual production is due to variance in winter intensity. For selection purposes, winter clutch size does furnish a significant criterion of annual egg record.

Annual production does not show linear regression on spring clutch by Blakeman's test. Therefore, the correlation ratio of .5024 with a positive sign expresses the true relationship. By squaring this constant .2524 is obtained to express the amount of variance in annual production that may be attributed to variance in spring clutch. Spring clutch size has, therefore, a high value in selecting for intensity.

The three months: March, April and May, making up the spring season all show non-linear regression of production on clutch size. In these data, April clutch size appears to be the most significant with a correlation of .3975, followed by May with .3498 and March with .3023. No single month in the spring season appears to give as good a measure of intensity as the combined three months.

Regression of annual production on summer clutch size is non-linear and the correlation ratio is .4238. This constant squared gives .1796 as the part of the variance in annual record associated with variance in summer clutch. This constant indicates that summer clutch size is of somewhat less importance than spring clutch size for the flock studied in so far as annual egg records are concerned. There is a possibility that spring clutch size has been reduced by the methods of selecting for high winter intensity and for greater persistency.

In a general sense, no one of the six short-time measures of intensity may be considered as an accurate criterion of the clutch size for the year. For the flock studied, spring clutch size is the best short-time measure. These data suggest that eight distinct types of intensity may occur:

Winter	*Spring*	*Summer*
High	High	High
High	High	Low
High	Low	High
Low	High	High
High	Low	Low
Low	Low	High
Low	High	Low
Low	Low	Low

Section A shows that high spring and high summer intensity are more likely to occur together than high winter and high spring or high winter and high summer. The same section also presents a significant correlation for intensity between any two of these seasons. In selecting breeders for maximum intensity, therefore, the clutch size throughout the first laying year offers the only reliable guide.

PRACTICAL APPLICATIONS

In breeding a flock for high intensity, the starting point is the selection as breeders of those females laying in large clutches in March, April and May. The next step is the selection of breeders with large spring clutch size and in addition winter clutch size of not under three eggs. Because of the intimate correlation between early sexual maturity and large winter clutch, it is also important that breeders carry early maturity. The third and final step in selection for high intensity is the addition of high summer intensity from June first to the close of the laying year. In order to establish uniform high intensity throughout the pullet laying year it is necessary to employ yearling breeders that exhibit large clutch size in winter, spring and summer.

SUMMARY

Intensity during three seasons of the pullet laying year is considered. Winter clutch size measures the intensity from first pullet egg to March first. Spring clutch size covers the period from March first to June first. Summer clutch size includes the time interval beginning June first and continuing to the close of the 365-day laying year.

March clutch size, April clutch size and May clutch size are each studied as possible short-time measures.

Winter clutch size and spring clutch size show a non-linear relation and the correlation ratio between the two is .4171.

Winter clutch size and summer clutch size also show a non-linear relation with a correlation ratio of .3091.

Spring clutch size and summer clutch size show a linear relation to each other and a coefficient of correlation of $+.4593 \pm .0130$.

Winter clutch size is correlated to a high degree with age at first egg.

The degrees of correlation between winter clutch size and winter pause duration, winter clutch size and days broody and winter clutch size and persistency are very moderate but slightly significant.

Spring clutch size shows non-linear regression on winter pause duration with a correlation ratio of .3596.

March clutch size, April clutch size and May clutch size are independent of age at first egg, winter pause duration, total days broody and persistency.

Summer clutch size is independent of age at sexual maturity, moderately correlated with winter pause duration and persistency and correlated to the extent of .3531 with total days broody.

As a criterion of annual egg production, the six short-time measures rank in the following order determined by the degree of correlation: spring clutch, summer clutch, winter clutch, April clutch, May clutch and March clutch.

In general, clutch size seems to increase somewhat following either a winter period of non-production or a broody period.

The mean clutch size for the flock studied was: winter, 3.35; spring, 4.07; and summer, 3.04.

The most significant short-time measure of intensity is spring clutch size, but no short-time measure of intensity is as accurate as the mean clutch size for the entire year.

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Publication of this Document Approved by Commission on Administration and Finance
3M-7-'32. No. 5841.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 287 JULY, 1932

Frozen Fruits and Their Utilization in Frozen Dairy Products

By M. J. Mack and C. R. Fellers

The frozen-pack method is used annually to preserve large quantities of fruit, much of which is later used for flavoring ice cream. Fruits used for this purpose have a very pronounced influence on the quality of the final product. Very little is known regarding the most satisfactory ways of processing fruit for utilization in frozen dairy products. The results reported here furnish some information on this subject.

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Figure 1. Containers for frozen-pack fruit. Left to right, empty 1-gallon friction top can, raspberries, sliced peaches, strawberries, 5-gallon slip cover can; in front a pint paper carton containing raspberries.

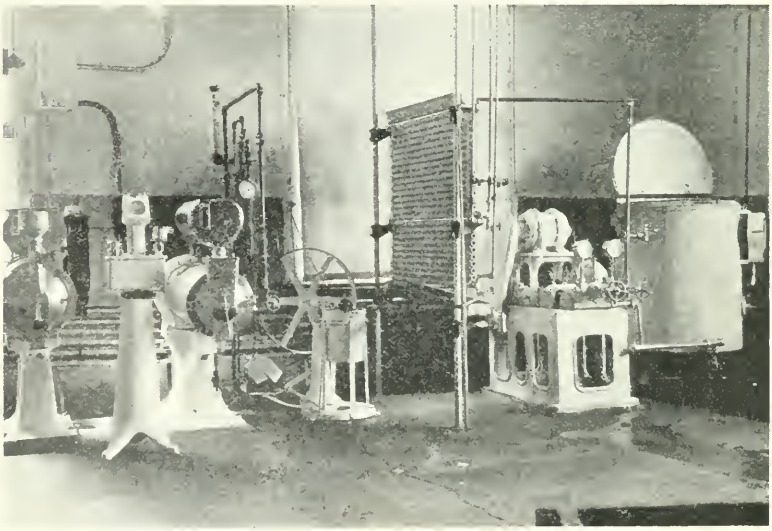

Figure 2. The equipment used for processing and freezing the ice creams made in this investigation.

FROZEN FRUITS AND THEIR UTILIZATION IN FROZEN DAIRY PRODUCTS

By M. J. Mack, Assistant Professor of Dairy Industry
and
C. R. Fellers, Research Professor of Horticultural Manufactures

INTRODUCTION

In 1931 approximately 350 million gallons of ice cream besides sherbets, ices and mousses were produced in the United States. Of this immense amount 15 to 16 per cent or 55 million gallons consisted of fruit ice cream. Strawberry, raspberry, pineapple, peach, cherry, and orange were the principal fruits used, though many others were utilized to a lesser extent. Strawberry made up 8 per cent of the total—28 million gallons. Next in importance came orange-pineapple.

This shows the tremendous possibilities to the fruit industry for supplying frozen-packed fruit for ice cream and similar dairy products. The soda fountain trade, also largely dependent on ice cream, uses large quantities of frozen fruits and no doubt could absorb still more.

In view of the somewhat limited knowledge concerning the best methods of freezing and of using frozen fruits, the writers investigated some phases of the problem. The fruit thus made available was utilized in ice cream and ices to determine the effect of fruit varieties and methods of preserving on the freezing and quality of the finished products.

Plan of the Investigation

Briefly, the plan of the investigation was to prepare experimental packs of the fruits in one-gallon cans, freeze these under known conditions, store for approximately one year, thaw, examine carefully, and finally use the fruit in the manufacture of fruit ice creams, sherbets and ices.

The study thus falls naturally into two parts: (1) A study of the methods of packing, handling, freezing and storage on the quality of the frozen fruit; and (2) the utilization of these frozen fruits in frozen dairy products. In general, these parts will be treated separately because the packer of frozen fruit is interested chiefly in the method of packing, handling and storage, while the ice cream manufacturer is interested more specifically in the use of frozen fruit in dairy products.

The term "frozen-pack" is used in this bulletin in preference to the older trade designation "cold-pack" for fruits frozen with sugar. The writers agree with Diehl (6) that the former expression is more accurately descriptive of the process actually involved.

Historical

In 1927 Turnbow and Cruess (17) concluded that properly prepared frozen-packed fruits were approximately equal to the fresh for use in ice cream and water ices. They advocated the use of higher percentages of fruit in ice creams than had been customary; for example, they recommended at least four pounds of fresh strawberries to 45 pounds of basic mix for a good strawberry ice cream. They likewise considered that most frozen fruits made more satisfactory ice cream and ices than dried, canned or pulped fruits. The Marshall variety of strawberry was found to give excellent flavored ice cream. Banner was unsatisfactory.

Fabricus (7), in Iowa, found that frozen strawberries were superior to either canned fruit or strawberry extracts in the manufacture of ice cream. He recommended Gandy, Kellogg's Prize, Early Jersey, Giant, and Dunlap as desirable varieties for use in ice cream. The optimum ratio of strawberries to sugar was two to three pounds of fruit to each pound of sugar. He found full-ripe fruit gave a superior flavored ice cream. Storage at temperatures above 25° F. resulted in definite quality deterioration.

Turnbow and Raffetto (18), also Sommer (15), give general information on fruit ice creams.

Since the inception of the frozen-pack method of preserving fruits in the Pacific Northwest about 20 years ago, many papers bearing on the general subject have appeared. Most of these are found in various trade journals and contain little actual data. However, the reports by Cruess (2), Joslyn (10, 11), Diehl (6), Wiegand (19), Woodroof (20, 21), Birdseye (1), Lathrop (12), Culpepper (3), and others, sum up the available information on the subject.

The present writers have also published preliminary reports of their findings in the ice cream and fruit products' trade journals (9, 13).

PART I. FROZEN FRUIT INVESTIGATIONS

Experimental Methods

Approximately 650 one-gallon cans of fruit were frozen packed for these experiments over a three-year period. About one-half of this amount consisted of strawberries; raspberries, cherries and peaches made up the rest. The fruits were all produced in the college orchards, picked when fully ripe, and in prime condition when packed.

The methods of investigation were varied in order to compensate for the differences among the different fruits studied. However, the same general procedure was followed as closely as possible. All fruit was prepared for packing (hulled, pitted or pared as the case might be) washed in cold water and drained. It was then weighed and the desired quantity of sugar mixed uniformly through the fruit. The fruit was then transferred to one-gallon enamelled, friction-top tin cans, properly labeled, moved into a storage room and held between 0° and 5° F. This insured rapid freezing. After a few days in this room (over night is sufficient) the fruit was transferred to another cold storage room held between 10° and 15° F. The fruit was removed as needed and melted at room temperature in 15 to 20 hours. After melting, observations were taken on the following points: color of fruit and syrup; flavor of fruit and syrup; proportion of fruit to syrup; size and texture of fruit; and consistency and clarity of syrup.

The effect of the following factors on the pack was studied:

1. Variety.
2. Proportion of fruit to sugar (variation from 20-50 per cent sugar).
3. Substitution of corn sugar for cane sugar (whole or part).
4. Syrup packs.
5. Freezing without sugar.
6. Fruit; whole, sliced or crushed.
7. Vacuum packing.
8. Standing before freezing.
9. Thawing and refreezing.

The melted frozen-packed fruit was used in ice cream in order to study the effect of the factors listed above. Therefore, an important part of this investigation has been a study of the effect of methods of freezing on the properties of fruit ice creams. These are described in Part II.

Frozen Strawberries

Variety Studies

Twenty of the more important northeastern varieties were frozen in the ratio of two pounds of fruit to one pound of sugar. These studies were carried on over a three-year period, 1929, 1930 and 1931. Approximately 130 cans were packed for the variety studies. The fruit was grown on a fertile, gravelly loam soil, picked when fully mature, and frozen the same day. The fill of the container was the same in the variety studies, i. e., the weight of contents was constant at five pounds. In general, the storage period at 10° to 15° F. was for 12 months. This allowed comparisons to be made with the freshly harvested fruit of the succeeding season.

Results of examination of the 2:1 packs are summarized in Table 1. Although comparisons were also made in these varieties where the ratio of fruit to sugar were 1:1, 2½:1, 3:1 and 4:1, the results are sufficiently like the 2:1 packs so that reproduction of all these data will be omitted. Fruit solids or "fruit" in the defrosted packs was determined by weighing the portion remaining after draining for two minutes on an 8-mesh sieve of 10 inches diameter.

Besides the 20 varieties classed in Table 1, commercial packs of Klondike, Ettersberg, and Marshall were also examined. All three rated very high in appearance and flavor both after freezing and in ice cream. The ratings given the several varieties are shown in Table 1 and require no discussion. It is noteworthy to observe the rather close limits for soluble solids, 5.9 to 7.6 per cent, and titratable acidity, 0.90 to 1.43 per cent. Of course, even the same variety will vary greatly with the degree of maturity. At least two pickings during the course of two seasons were considered in determining the number of berries per pound. This method gives an excellent comparative idea of the size of the individual fruits. Flavor, appearance and other organoleptic properties of frozen fruit were judged by groups of several men with experience in the examination of fruit products. In general, the varieties which were considered best flavored when fresh, were also best both after freezing and after incorporation into fruit ice cream. The more acid varieties were usually unsatisfactory. The varieties which have a red or pink flesh, such as Howard Supreme, Senator Dunlap, or Aberdeen, gave more highly colored frozen products than the light-fleshed varieties. There was slight surface darkening in all the packs, no significant differences being noted among the several varieties. For most varieties 2.5 to 3 pounds of fruit to the pound of sugar gave a frozen product of optimum flavor. A few of the sour varieties were best when packed with sugar in the ratio of 2:1. More data bearing on the ratio of fruit to sugar are presented in Table 2. In no case did ratios of fruit to sugar, greater or less than 2:1, cause any significant change in rating of any variety of fruit. That is, there was no advantage gained in comparing the freezing qualities of varieties of fruits at ratios of fruit to sugar other than 2:1.

Effect of Varying the Ratio of Berries to Sugar

For this experiment both mixed variety, field-run strawberries and separate varieties were used. All were harvested in 1929, 1930 and 1931. The purpose of the work was to determine the most satisfactory fruit to sugar ratio in frozen packs for use in ice cream. In all, 97 one-gallon cans were packed. The fruit-sugar ratios used were 1:1, 2:1, 3:1, 4:1 and 1:0. The fruit was prepared and frozen as described in the variety tests and was examined from 11 to 16 months after packing. The data are summarized in Table 2.

TABLE 1.—CHARACTERISTICS OF FRESH AND FROZEN STRAWBERRIES, AND STRAWBERRY ICE CREAM.

Variety	Fresh Fruit					Frozen Fruit—after 1 year			
	Number per pound	Color	Flavor	Soluble solids	Acidity (citric)	Rating	Syrup concentration	Ratio of fruit : syrup	Rating in ice cream
				Per cent	Per cent		Degrees Brix		
Howard 17	111	Excellent	Good	6.3	0.96	Excellent	41.3	1 : 1.33	Very good
Howard Supreme	92	Good	Excellent	6.1	1.11	Excellent	41.5	1 : 1.46	Excellent
Sample	76	Poor	Poor	5.9	0.92	Poor	33	1 : 0.93	Poor
Marshall	69	Good	Excellent	7.5	0.90	Good but soft	38	1 : 1.1	Good
Mastadon	62	Fair	Good	7.4	1.2	Fair	40	1 : 0.66	Fair
Champion	158	Excellent	Good	6.3	1.2	Very good	40.2	1 : 1.23	Very good
King Edward	96	Good	Excellent	7.5	1.2	Excellent	38.5	1 : 0.69	Excellent
Bun	96	Poor	Excellent	7.1	1.3	Fair	34	1 : 1.09	.....
Beacon	74	Poor	Fair	6.9	1.05	Good	37	1 : 1.27	Good
Boquet	74	Fair	Good	6.4	1.16	Poor	38.2	1 : 1.26	Excellent
Heritage	70	Fair	Poor	6.9	1.2	Poor	41	1 : 1.06	.....
First Quality	100	Excellent	Good	6.8	1.14	Excellent	42	1 : 1.26	Very good
Bliss	102	Fair	Good	7.0	1.03	Fair	36	1 : 1.12	Fair
Stevens Late Champion	72	Fair	Good	6.5	1.43	Fair	44	1 : 0.74	Fair
Meteor	52	Good	Fair	5.9	1.2	Good	38	1 : 0.96	Fair
Commonwealth	60	Good	Very good	7.6	1.02	Very good	41	1 : 1.1	Fair
Senator Dunlap	90	Good	Poor	6.0	1.4	Fair	37	1 : 0.62	Poor
Progressive	136	Good	Good	6.3	1.96	Good	39	1 : 1.2	Fair
Aberdeen	90	Good	Excellent	7.0	1.16	Excellent	33	1 : 1.3	Excellent
Marvel	136	Poor	Fair	6.8	0.97	Fair	39.5	1 : 0.93	Poor

TABLE 2.—EFFECT OF VARYING FRUIT TO SUGAR RATIOS IN FROZEN STRAWBERRY PACKS.

Ratio of Fruit : Sugar	Fruit			Syrup					
	Color	Flavor	Size and texture	Color and clarity	Flavor	Sugar	Ratio of fruit to syrup	Rating	Rating in ice cream
						Per cent			
1 : 1*	Good	Marked by high sugar	Considerable shrinkage and disintegration	Color high but debris from broken berries	Over-sweet	50	1 : 1.72	Poor	Poor, too soft and sweet
1½ : 1*	Very good	Good	Much shrinkage, firm	High	Good	46	1 : 1.5	Fair	Fair, too sweet and soft
2 : 1*	Excellent	Excellent	Some shrinkage but no disintegration	Color good and clarity excellent	Excellent	38.2	1 : 1.25	Very good	Very good
2½ : 1	Good	Excellent	Moderately firm, little shrinkage	Very good	Excellent, slightly tart	35	1 : 1.03	Excellent	Excellent
3 : 1	Excellent	Natural but tart	Very little shrinkage, no disintegration	Color good, syrup clear	Tart	32.3	1 : 1	Very good	Very good
4 : 1	Natural red	Too sour	Very little shrinkage, slow to melt	Color poor, clear syrup	Sour	28.6	1 : 0.89	Fair	Poor, too sour
1 : 0	Dull brown	Flat and unnatural	Very little shrinkage, very slow to melt	Color light but clear	Very sour	7.7	1 : 0.78	Poor	Poor, unnatural acid
Dextrose 2 : 1 pack*	Dark, unnatural purplish-red	Flat and poor, unnatural	Soft and disintegrated. Grayish red precipitate not readily soluble. Slow to melt	Purple, full of granular sediment	Flat and unnatural	26	1 : 1.3	Poor	Poor color, poor, soft
½ Dextrose ½ Sucrose 2 : 1 pack*	Slightly darkened. Deep wine red	Somewhat unnatural	Soft, shrinkage evident. Some disintegration	Color deep red. Some sediment	Unnatural	39	1 : 1.4	Fair	Poor, soft, unnatural
⅔ Dextrose ⅓ Sucrose 2 : 1 pack*	Unnatural, dark purplish red	Flat, objectionable	Soft and broken. Fully ½ inch of purple sugar sludge. Slow to melt.	Darkened, unnatural. Muddy from crystal sludge	Flat, unnatural	38.6	1 : 1.3	Poor	Poor
⅓ Dextrose ⅔ Sucrose 2 : 1 pack*	Trifle deeper red than all sucrose pack	Good	Some shrinkage and disintegration	Color good but contains broken berry parts	Good	38.9	1 : 1.3	Fair	Fair

* Undissolved sugar present.

Packing without sugar proved impracticable. The natural color and much of the flavor of the fruit was lost. Without a sugar syrup present, the color is destroyed, probably through oxidative changes. Sugar syrup absorbs and retains volatile compounds which are lost in a pack without sugar. The sugar probably prevents the deterioration of the volatile flavoring substances as well as absorbing them.

Attempts to substitute dextrose (corn sugar) for sucrose were unsatisfactory. Dextrose caused the fruit to darken and assume an unnatural purplish-red appearance. The seeds turned black as well as the tips of the berries. The flavor of the fruit was flat, unnatural, and objectionable. The fruit in the dextrose pack became very soft and mushy, and disintegrated to a considerable extent. These changes may be due to a greater osmotic concentration of the dextrose syrup since the molecule is only one-half as large as that of cane sugar. The greatest objection, however, to the dextrose pack was the presence of a grayish-red, granular substance which formed a crust on the surface and a sludge at the bottom of the can. This substance was not readily soluble, hence caused the fruit to melt slowly and remained as a precipitate in the syrup to a considerable extent unless it was dissolved by warming the fruit. The substance was identified as dextrose crystals (probably dextrose monohydrate) by the osazone test.

Corn syrup or dextrose (which is known by the trade name of cerelose) is bleached with sulfur dioxide in the process of manufacture. It is to this residual sulfur dioxide in the cerelose that this discoloration is attributed. The sample of cerelose used in this study contained 19 parts per million of sulfur dioxide. The purple color is formed by the interaction with tin of the anthocyans (red pigments) of the fruit. The sulfur dioxide accelerates this corrosive action and thus indirectly impairs both flavor and color.

A 2:1 pack in which two-thirds of the sugar was dextrose was similar to the all-dextrose pack but not as outstanding in its defects. The defects were less marked where only one-half of the sugar was dextrose, yet some of the grayish-red substance cited above was evident. None was present where only one-third of the sugar was dextrose. However, the color was purplish-red and appeared somewhat unnatural. The flavor was not as desirable as that of an all-sucrose pack.

Since cane sugar was found to be the more desirable sugar, another factor to be considered was the ratio of berries to sugar. Table 2 shows that the 2:1, 2½:1 and 3:1 packs were the most desirable. The 1:1, and 1½:1 packs were too sweet and the true flavor of the fruit was masked. The higher osmotic pressure brought about considerable shrinking and disintegration of the fruit. Too much cloudy syrup was evident due to the presence of seeds and other debris from the disintegrated berries. The 4:1 pack showed practically no shrinking or disintegration and had an excellent color. However, the fruit was too sour and the syrup too thin and watery.

A choice between the 2:1 and 3:1 packs was hard to make and would probably depend upon the use for which the fruit is desired. Each of the two packs had distinct advantages. The flavor of the fruit and the consistency and flavor of the syrup were a little superior in the 2:1 pack. The advantages of the 3:1 pack were larger and firmer berries, less syrup, better color, less danger of undissolved sugar in the syrup, and less weight per gallon for transportation. Probably the 2½:1 ratio is the best for most purposes.

Few attempts have been made to investigate frozen-packing from the standpoint of temperature effects. The fruit was placed in a room at 0° F. or slightly lower for a few days to insure rapid freezing, and was later removed to a room held between 10° and 15° F. The necessity for rapid cooling to prevent fermentation has been disclosed (6). However, the fruit should not remain at this

lower temperature too long or a sugar sludge will form at the bottom of the containers. Fruit held below 0° F. for as long as two weeks had a sugar sludge at the bottom of the cans which did not disappear until the fruit had been held six months at the higher temperature of 10° to 15° F. This trouble was not noticed if the fruit was moved into the second room after two or three days and did not appear under any conditions with the 3:1 pack. Undissolved sugar was always present in the 1:1 and 1½:1 packs and was often present in small amounts in the 2:1 packs after defrosting. This excess of sugar does not aid in any way in preserving the fruit. Where the ratio of fruit to sugar exceeded 2½:1, no undissolved sugar was found in any fruit.

Effect of Freezing the Berries with Sugar Syrups

Because of the difficulties of thoroughly mixing the fruit with sugar in the frozen packs, sugar syrups were used in an effort to obviate this difficulty, save time, and possibly prevent crushing the fruit.

Several experimental packs were made in which cane sugar syrup was substituted for dry sugar. Thirty 1-gallon cans were used in the tests in 1930 with both mixed varieties and Howard 17. Since no differences were evident in the several different packs, all are considered together in Table 3. The berries were simply covered with the syrup of desired concentration, no definite weight being used.

There was a definite decrease in the surface discoloration of the syrup packs as compared with the dry sugar packs. The syrup exerted a protective action against oxidation. The optimum syrup concentrations for freezing strawberries were 40 and 50 per cent. Eighty per cent invert syrup, and 65 per cent sugar syrup were too concentrated, causing the berries to shrivel and float on the surface. The color was good, however, in the 60 and 65 per cent syrup packs. The appearance and flavor of the 40 and 50 per cent syrup frozen strawberries were considerably better than those of either higher or lower sugar concentrations.

There are definite advantages in a syrup pack. Among these are: less air discoloration, less damage to the fruit, greater convenience, and firmer textured fruit. There is no loss of undissolved sugar, and spoilage is less likely to result. Also if the syrup is chilled before using, it acts as an effective precooling agent. Where facilities for making and storing syrups are available, the use of syrup in place of dry sugar is entirely feasible. The principal objection to the use of syrup is that additional water (and weight) is thereby added to the product. The preparation of small batches of syrup is also inconvenient. Experience has shown that the amount of syrup to be added may be judged satisfactorily by simply covering the fruit.

Effect of Delay Between Packing and Freezing the Berries

In commercial practice it is often difficult to avoid delays incident to freezing the fruit. In order to determine the effect of varying storage periods before freezing, 40 one-gallon cans of Howard 17, 2:1 strawberries were packed in 1930. The berries were fully matured and of good quality. They were either frozen immediately after mixing with sugar or else allowed to stand for definite time intervals before freezing at—5° F. Two storage temperatures were used, 45° and 80° F., corresponding respectively to common cold storage and normal July temperatures. The fruit was examined both before freezing and after defrosting a year later. Representative samples were used in strawberry ice creams. The data are tabulated in Table 4.

TABLE 3.—FREEZING STRAWBERRIES WITH SUGAR SYRUPS.

Sugar syrup concentration	Ratio of fruit : syrup	Sugar in syrup	Texture of fruit	Color	Flavor	Surface discoloration	Rating in ice cream
Per cent		Per cent					
80 (invert)	1 : 1.8	43.0	Tough, much shrinkage	Poor	Poor, too sweet	Moderate in fruit above syrup	Poor
65	1 : 1.45	41.0	Very firm	Good	Poor, too sweet	Slight in fruit above syrup	Fair, sweet
60	1 : 1.2	38.6	Good, slight shrinkage	Very good	Good	None	Fair, sweet
50	1 : 0.98	37.8	Good	Very good	Excellent	None	Very good
40	1 : 0.9	33.5	Good, slightly soft	Good	Very good	None	Excellent
30	1 : 0.7	18.5	Soft	Poor	Fair, too sour	Very slight	Fair, slightly sour
Dry sugar 2½ : 1	1 : 1.1	35.0	Good	Good	Excellent	Slight	Excellent

TABLE 4.—EFFECT OF DELAYED FREEZING ON THE QUALITY OF FROZEN HOWARD 17 STRAWBERRIES (2 : 1 PACK).

Time interval between packing and freezing	Temp. of holding	Condition prior to freezing	Sugar content of syrup	Ratio of fruit : sugar after defrosting	Flavor	Color	Texture	Rating after defrosting	Rating in ice cream
Hours	°F.		Per cent						
0	....	Excellent* no syrup	36	1 : 1.3	Excellent	Good	Slightly soft	Good*	Very good
3	45	Excellent	31.5	1 : 1.5	Excellent	Excellent	Slightly soft	Excellent	Very good
6	45	Excellent slight syrup	33.5	1 : 1.7	Excellent	Excellent	Firm	Excellent	Very good
12	45	Good, considerable syrup	35.3	1 : 1.6	Excellent	Very good	Firm	Very good	Very good
24	45	Fair, much syrup	35.3	1 : 1.5	Excellent	Excellent	Tough	Good	Very good
3	80	Excellent, slight syrup	36.3	1 : 1.2	Excellent	Excellent	Firm	Excellent	Very good
6	80	Excellent, considerable syrup	34	1 : 1.3	Excellent	Good	Firm	Very good	Very good
12	80	Fair, much syrup	36.5	1 : 1.3	Good	Good	Firm	Fair	Good
24	80	Poor, slight fermentation	35	1 : 1.4	Poor, slight fermentation	Fair, discolored	Poor, slightly gassy	Poor, slight mold at surface	Fair

*Slight amount of undissolved sugar.

The table is largely self-explanatory. There was apparently no injury to the quality of the frozen pack when held 12 hours at 45° F. or 6 hours at 80° F. In fact a short holding period dissolves all the sugar, and by allowing osmotic action to proceed, thoroughly impregnates the fruit with sugar. This action seems to aid in overcoming enzymic discoloration from oxygen within the fruit. Similarly, delayed freezing draws out some of the juices from the fruit so that the appearance is similar to a syrup pack but without the disadvantage of added water.

Up to 6 hours holding at summer temperatures did not injure the quality of the fruit. However, after 12 hours, there was a lack of fresh fruit flavor and too much bleeding of the fruit; and after 24 hours, slight yeasty fermentation and surface molding had begun. Obviously it is better to hold strawberries in a pre-cooler than at room or outside temperatures because of the deteriorative influences of the latter. During the holding period the fruit appears first to give up juice to a certain point and then reabsorbs it so that finally equilibrium is reached. In the case of a 2:1 pack of strawberries this point is at a syrup concentration of about 35-36 per cent sugar.

The Effect of Vacuum Packing

With a view to overcoming surface discoloration in frozen strawberries, 27 one-gallon cans of strawberries were packed in 1930 at Gloucester, where a vacuum sealing machine for gallon cans was available. The berries were well colored, mature, yet firm in texture. Ratios of 2:1, 2½:1 and 3:1 of fruit to dry sugar and 80, 65, 50 and 40 per cent syrup packs were employed. Vacuums of 10-12 and 18-22 inches of mercury were used. Controls in the usual friction-top unsealed cans were likewise packed. The berries were frozen at 0° F. and stored at that temperature for 11 months before defrosting and examination.

Inasmuch as the results showed few essential differences from other sugar or syrup packs already recorded in Tables 1, 2 and 3, the data are not given. The outstanding observation was that the vacuum-packed fruit showed no surface discoloration. That is, the air (oxygen) in the headspace of the cans had been largely removed by vacuumization, and did not cause deleterious oxidations which injure both color and flavor of the surface layer of fruit.

The fruit packed at vacuums of 18-22 inches was somewhat better than that packed at lower vacuums, probably because of more effective oxygen removal. As stated previously in this bulletin, the 2½:1 and 3:1 dry sugar packs were considered best from the ice cream manufacturer's viewpoint; and of the syrup packs, the 40 and 50 per cent were considered superior in appearance and flavor both after defrosting and when manufactured into ice cream. The 80 and 65 per cent syrups gave unsatisfactory packs in that both were too sweet and required too large quantities to cover the fruit. The berries also floated so easily that they could not be readily packed into the cans. Vacuums in excess of 20 inches could not be secured in one-gallon (No. 10) cans because of paneling effects. That is, the sides of the can would yield to the high vacuum and become concave, thus reducing the can volume as well as vacuum. Several cans were totally ruined when attempts were made to secure vacuumization at the 25-inch level. With smaller cans, it would be feasible to use vacuums of 25 inches or even more, because they are sufficiently strong to withstand such strains.

Several glass jars of strawberries and other fruits were vacuum sealed at 25 inches and frozen with good results. In fact, glass jars of frozen fruits make a very attractive appearance. Care must be taken in packing glass jars that sufficient headspace is allowed to compensate for the expansion due to freezing. About one-half inch is sufficient for pint or quart glass jars.

Effect of Crushing or Slicing the Berries

Crushed and also sliced strawberries were frozen-packed for comparsion with the whole fruit. The frozen crushed fruit was inferior in appearance because of a faded-out, unattractive color. The surface layer of fruit was also rather badly discolored. The flavor was not normal. On the other hand the sliced fruit retained well its color and flavor. No significant flavor differences could be detected in ice creams made from sliced or whole fruit. Both the sliced and crushed 2:1 strawberries gave a sugar percentage in the syrup of 36, with a fruit to sugar ratio of 1:1.05. These values are very similar to those for whole 2:1 strawberries.

Frozen Raspberries

Several varieties of raspberries were frozen packed in 1929 and 1930 by the same methods that were used for strawberries. Variety, ratio of fruit to sugar, and a few syrup packs were frozen. The raspberries were full-ripe when packed. The more important results are tabulated in Table 5. In all, 66 one-gallon cans of raspberries were packed. Sugar ratio experiments were made for Cuthbert and Herbert varieties as well as St. Regis, but the results were very similar and hence are not presented separately. Several varieties were packed with a 4:1 ratio of fruit to sugar but with less satisfactory results than when the 3:1 ratio was used. St. Regis raspberries are very seedy. Several gallons of the defrosted berries were passed through a tomato pulper and the resulting seedless pulp made into ice cream and ice. The yield of seedless pulp was 84 per cent in this trial. The dry weight of seeds in Cuthbert and Herbert varieties was found to be 8 and 7.3 per cent respectively. The removal of seeds in raspberries overcomes one of the principal objections to the use of this fruit in ice cream, jams or even as a dessert.

Of the varieties of raspberries frozen, Cuthbert, Herbert and St. Regis were most satisfactory both as frozen fruits and when used in ice cream. Though small and seedy, the St. Regis possessed a good flavor and color. The purple and black varieties as well as Ontario and Newman were of poor quality. The black raspberries shriveled badly and were very tough and seedy.

Raspberries frozen without sugar were of poor flavor and color as compared with those containing sugar. The fruit did not stand up after defrosting. Dextrose packs were poor in quality, the same defects being noted as in frozen strawberries. The use of dextrose (corn sugar) cannot be recommended in frozen fruits.

The main difference in the raspberry packs was the distinct superiority of the 3:1 over the 2:1 fruit to sugar ratio. This was true in every variety tested. Surface discoloration was always more marked on the fruit containing the least sugar. As with strawberries, the fruit shrunk less and had less color in the less concentrated sugar packs. It should be stated that all varieties of raspberries have a distinct and fairly permanent characteristic flavor and that the differences among varieties are not so great as in the case of strawberries.

Frozen Peaches

Peaches were frozen in each of the three years of the investigation. All were harvested and frozen when fully mature. They were prepared for freezing by lye-peeling in 5 per cent caustic soda solution, rinsing in clean, cold water followed by trimming and slicing into eighths. Approximately 130 one-gallon cans were frozen. Because of close similarities among varieties and ratios of fruit to sugar, only representative samples are included in Table 6.

Of the common New England-grown varieties tested, Hiley, Elberta, Hale, Crawford and Belle of Georgia gave the most promising frozen packs. These

TABLE 5.—EFFECT OF VARIETY AND SUGAR RATIOS IN FROZEN RASPBERRIES.

Variety	Ratio of fruit : sugar	Color	Flavor	Texture	Surface discoloration	Sugar content of syrup	Ratio of fruit : syrup	Rating in ice cream
						per cent		
St. Regis	1 : 1	Excellent	Good	Soft	Slight	56	1 : 1.6	Good
St. Regis	2 : 1	Very good	Very good	Moderately firm	Slight	46	1 : 1.3	Good
St. Regis	3 : 1	Very good	Very good	Soft	Moderate	33.6	1 : 1.2	Very good
St. Regis	1 : 0	Fair	Poor	Soft	Much	9	1 : 0.75	Fair
St. Regis	2 : 1 (dextrose)	Poor	Poor	Soft	Very much	.....	.....	Poor
Cuthbert	2 : 1	Excellent	Excellent	Firm	Slight	46	1 : 1.4	Excellent
Cuthbert	3 : 1	Very good	Excellent	Slightly soft	Moderate	34	1 : 1.2	Excellent
Herbert	3 : 1	Very good	Excellent	Moderately firm	Moderate	36	1 : 0.9	Excellent
Latham	3 : 1	Fair	Very good	Moderately firm	Slight	32	1 : 1.8	Good
Newman	3 : 1	Fair	Good	Soft	Moderate	33	1 : 1.3	Fair
Ontario	3 : 1	Poor	Good	Soft	Much	32	1 : 1.4	Fair
Columbian Purple	3 : 1	Poor	Good	Soft	Moderate, unnatural color	37	1 : 1.09	Poor
Plum Farmer Black	3 : 1	Poor	Good	Firm, seedy	None	36	1 : 1.07	Poor

TABLE 6.—EFFECT OF VARIETY AND SUGAR RATIOS IN FROZEN PEACHES.

Variety	Ratio of fruit : sugar	Color	Flavor	Texture	Surface discoloration	Sugar content of syrup	Ratio of fruit : syrup	Rating in ice cream
						per cent		
Carman	2 : 1	White to yellow	Good	Firm	Very slight	44.4	1 : 0.84	Good
Carman	3 : 1	White to light yellow	Very good	Firm	Slight	36.5	1 : 0.72	Good
Belle of Georgia	2 : 1	White	Good	Medium	Moderate	45.6	1 : 0.87	Fair
Belle of Georgia	3 : 1	White	Good	Medium	Moderate	38.5	1 : 0.7	Fair
Greensborough	2 : 1	Greenish white	Poor	Very firm	Much	45.3	1 : 0.84	Poor
Greensborough	3 : 1	Pale, poor	Poor	Very firm	Much	38.0	1 : 0.75	Poor
Hiley	2 : 1	Cream white	Excellent	Slightly soft	Moderate	42.5	1 : 0.76	Very good
Hiley	3 : 1	Clear white	Excellent	Soft	Moderate	35.5	1 : 0.53	Very good
J. H. Hale	3: 1	Deep yellow	Excellent	Medium	Slight	42.0	1 : 0.61	Very good
Crawford	3 : 1	Deep peach yellow	Excellent	Soft	Moderate	38.5	1 : 0.79	Very good
Champion	3 : 1	Pale	Good	Soft	Moderate	40.0	1 : 0.57	Good
Elberta	3 : 1	Deep yellow	Very good	Slightly soft	Much	35.5	1 : 0.51	Very good

TABLE 7.—CHARACTERISTICS OF FROZEN-PACK CHERRIES AND MISCELLANEOUS VARIETIES OF FRUITS.

Variety	Ratio of fruit : sugar	Color	Flavor	Texture	Surface discoloration	Sugar content of syrup	Ratio of fruit : syrup	Rating in ice cream
						Per cent		
Montmorency Cherry	1 : 1	Red	Excellent	Firm	Very slight	58	1 : 0.92	Good
Montmorency Cherry	2 : 1	Red	Slightly sour	Firm	Slight	44	1 : 0.9	Good
Montmorency Cherry	3 : 1	Red	Too sour	Firm	Moderate	32	1 : 0.77	Fair
Montmorency Cherry	2 : 1 (dextrose)	Red	Fair	Firm	Marked	41	1 : 0.96	Fair
Morello Cherry	2 : 1	Deep red	Good but sour	Firm	Very slight	43	1 : 0.93	Fair
Early Richmond Cherry	2 : 1	Light red	Fair, sour	Firm	Moderate	42	1 : 0.64	Fair
May Duke Cherry	2 : 1	Dark red	Sub-acid	Firm	Very slight	44	1 : 0.89	Good
Evergreen Blackberries	2 : 1	Black to brown	Sour, poor	Firm	Marked	43	1 : 1.02	Poor
Wild Blackberries	2 : 1	Black	Good	Slightly soft	Slight	46	1 : 0.98	Poor
Cranberries	1 : 1	Red	Good, very acid	Very firm	None	51	1 : 0.37	Fair, good in ice
Damson Plums	1 : 1	Blue	Good, acid	Firm	Slight	56	1 : 0.64	Fair in ice
Red Currants	2 : 1	Red	Fair, very acid	Soft	Moderate	45	1 : 0.75	Fair in ice
Rhubarb	1 : 1	Green to pink	Fair, very acid	Moderately firm	Slight	51	1 : 0.47	Poor
Nectarines	3 : 1	Deep purple	Very good	Medium	Slight	38.5	1 : 0.43	Good

same varieties were best in ice cream as well. Both white and yellow-fleshed varieties were of good quality. In general, the early-season varieties were somewhat inferior to the mid-season ones.

All the varieties lost flavor upon freezing and defrosting and lost still more when made into ice cream or sherbet. In fact but little peach flavor was evident in the pure fruit peach ice creams.

Culpepper (3) made a study of the suitability of Georgia peach varieties for ice cream manufacture. He found Belle, Carman, Yellow Hiley and Elberta were very desirable varieties for this purpose.

The frozen peaches had a uniformly attractive appearance. The yellow varieties were most attractive, but all were of very pleasing color and flavor. The optimum ratio of fruit to sugar in most varieties of mature peaches seems to be about 3:1. No particular advantage was noted in the syrup packs. The flavor of the frozen peaches was noticeably superior to that of canned peaches of the same variety.

Frozen Cherries and Miscellaneous Fruits

In order to determine the suitability of various varieties of cherries and some other New England-grown fruits for freezing, mature Montmorency, Early Richmond, Morello, and May Duke cherries, as well as Damson plums, nectarines, cranberries, blackberries, red currants, and rhubarb, were frozen in various ways as described earlier under strawberries. Some 112 one-gallon cans of these miscellaneous fruits and rhubarb were packed and frozen over a three-year period. These were examined as usual after approximately one year in freezing storage at + 10° F. Some of the data are recorded in Table 7.

The cherries used were all sour varieties except May Duke. Montmorency was outstanding in its excellence as a frozen fruit, though Morello and Duke were also very satisfactory. For sour cherries a 2:1 pack proved best from the viewpoint of appearance, flavor, and suitability for use in pies or in frozen dairy products. Sour cherries are little used in commercial ice creams at the present time. These cherries made satisfactory products but lacked flavor. The color was particularly attractive. It should be noted that in a frozen pack of cherries there is considerably more fruit than syrup, thus differing from most berry varieties.

Both wild and Evergreen blackberries yielded frozen packs of only fair quality. The flavor was good but the appearance unattractive. The same was true of red currants, Damson plums and rhubarb. However, these made frozen ices of characteristic flavor.

Nectarines, when used in ice cream, produced a flavor greatly resembling peach. The frozen product, while not particularly attractive in appearance, possessed a pleasing flavor.

Cranberries were frozen whole, sliced, and as cranberry pulp, with and without sugar. The fruit kept perfectly regardless of the method of packing. Sliced cranberries or cranberry pulp frozen with sugar in a 1:1 ratio were judged the best packs in appearance and flavor. The pulp was especially satisfactory for use in frozen ices. In ice cream, the cranberry lost its characteristic flavor.

PART II. STUDIES OF FRUIT ICE CREAMS AND ICES

Experimental

The fruit available from the studies reported in Part I was utilized in ice cream to determine the effect of methods of packing on flavor and other characteristics. Other factors investigated in the making of fruit ice creams were:

1. Comparison of fresh and frozen fruits.
2. Effect of the percentage of fruit.
3. Time of adding fruit during freezing.
4. Effect of fruit on rate of freezing and properties of the ice cream.
5. Addition of vanilla and fruit extracts.
6. Causes of off-flavor in fruit ice creams.

Since strawberry is the most popular fruit ice cream, a principal part of the study was devoted to it. Raspberry, cherry, pineapple, and peach ice creams and ices were also investigated following the same general procedure used for strawberry. The experimental work with strawberry ice cream is discussed in detail. Properties and observations peculiar to other fruit ice creams are then discussed briefly. This is followed by a discussion of fruit ices.

All fruit ice creams contained 15 per cent by weight of the fruit being studied, unless a statement is made to the contrary. Freezing data were secured by taking the temperature of the mix in the freezer and the percentage of overrun at minute intervals throughout the freezing process. The ice cream was held at hardening-room temperatures (0-5° F.) for a few days before it was judged. The judges were students and members of the college staff, mostly not specialists in dairying and therefore representing fairly well the general consuming public. A three to one preference was assumed to be significant.

The ice cream mix used averaged 14.5 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.35 per cent gelatin. It was pasteurized at 150-155° F., held 30 minutes, and homogenized at 3,000 pounds pressure at the pasteurization temperature. The mix was aged from 5 to 24 hours before freezing. A 40-quart brine freezer was used, with brine varying from −5 to 2° F. in temperature. All samples of ice cream for judging were drawn from the freezer at the same temperature and at an overrun of 85-90 per cent, and were hardened for a few days before examination.

Acidity readings were determined by titrating a 9-gram sample with one-tenth normal sodium hydroxide with phenolpthalein as indicator. Hydrogen ion determinations were made electrometrically, using a Leeds-Northrup potentiometer with the quinhydrone electrode at 77° F.

Strawberry Ice Cream

Desirable Varieties for Use in Ice Cream

A comparison of the common New England varieties of strawberries over three fruit crops was made. On the basis of the trials, the strawberry varieties studied may be grouped as follows in respect to their comparative value for flavoring ice cream (see also Table I):

Excellent: Howard Supreme and King Edward.

Very good: Marshall, Howard 17, First Quality.

Fairly good: Aberdeen, Boquet, Beacon, Bliss, Commonwealth, Progressive.

Somewhat lacking in flavor: Marvel, Meteor, Mastadon, Sample, Senator Dunlap, Stevens Late Champion, Bun and Heritage.

Differences were in evidence among varieties from year to year which would indicate that among the leading varieties, seasonal effects, ripeness of fruit, etc.,

are factors of major importance. New England berries are fully equal in quality to Western or Southern grown fruit, and locally grown berries were fully as desirable as the commercial packs used for flavoring ice cream, if not superior to them.

Effect of Amount and Kind of Sugar Used

In preliminary reports of this investigation (9, 13) the writers showed that cerelose could not be substituted for cane sugar if good results were to be secured. Darkening of the fruit, crystallization of the sugar, and excessive shriveling and softening of the berries resulted when cerelose was used. The use of cerelose-packed frozen fruit in strawberry ice cream injured both flavor and appearance of the product.

The effect of the quantity of cane sugar used in frozen fruit on the appearance of the pack was discussed in the first part of this report (see Table 2). When used in ice cream the 1:1 packs made a very sweet, soft ice cream while the 4:1 packs did not impart a desirable strawberry flavor. The 2:1 and 3:1 packs imparted a more desirable flavor than all others. From the large number of ice cream samples judged in this study in 1929 and 1930, the conclusion was reached that an ice cream mix containing less than 15 per cent sugar should be flavored with 2:1 packed strawberries, but the 3:1 ratio should be used where the mix contains more than 15 per cent. However, in 1931 a ratio of 2.5:1 was used to a considerable extent and was considered preferable to any other ratio when the standard mix contained approximately 15 per cent sugar.

The Effect of Using Sugar Syrup and Vacuum Packing

An undesirable factor found in the standard sugar packs was oxidation of fruit at the surface. Berries not covered by the syrup were discolored and had lost part of their flavor. In the first part of this report, the advantages of using a cane sugar syrup or vacuum packing to decrease surface discoloration were discussed. Syrups containing 30, 40, 50, 60 and 65 per cent sucrose, as well as 65 and 80 per cent invert sugar, were used in different frozen packs and in ice cream (see Table 3). The rating of the ice cream was as follows: that containing 40 and 50 per cent syrup, first and second, respectively, with little choice, if any, between the other samples. The ice cream containing fruit packed in invert syrup seemed inferior to that containing cane sugar syrup. Neither the standard sugar packs nor those containing sugar syrup were improved for flavoring ice cream by packing in sealed cans from which a part of the air had been expelled by vacuumization before freezing.

Little difference was observed between the 2:1 and 3:1 sugar packs, those containing 40 or 50 per cent sugar syrup, and the vacuum packs. These observations indicate that the ice cream maker may safely buy frozen fruit packed by any of these methods. From the standpoint of flavoring ice cream, it is evident that the quality of the fruit is of greater importance than whether it has been packed in sugar, sugar syrup, or under vacuum.

Effect of Delay Between Packing and Freezing Fruit

No differences were evident in the flavor of ice creams made from strawberries which had been held for 6-24 hours at 45° F. between the time of packing with sugar and freezing (see Table 4). This treatment affected the appearance of the fruit and the ratio of fruit to sugar in the defrosted product. However, no flavor was lost from the pack so long as the holding period did not allow fermentation. In allowing fruit to remain unfrozen for several hours, more

flavor was drawn into the syrup but the degree of flavor in the combined fruit and syrup remained unchanged.

Effect of Slicing or Crushing Berries Before Freezing

Since ice cream makers have used both crushed and sliced fruit as well as whole, it seemed advisable to determine what effect these methods of treating the fruit before freezing had on the finished pack as well as on ice cream. The appearance of the crushed berries after thawing was not desirable, and more surface discoloration was evident than with whole fruit. Although the majority of those criticising the samples of ice cream made from whole and crushed fruit could not differentiate between them, nevertheless, the more experienced judges invariably preferred those samples made from the whole fruit.

Slicing berries into thirds or quarters gave better results than crushing the fruit. The sliced fruit showed no greater surface discoloration during storage than whole fruit. Though less syrup was evident in the thawed sliced fruit samples due to the finer division of the fruit through the syrup, still, very little quality difference was found between ice cream made from whole or sliced berries. A slight preference was shown for the ice cream flavored with the sliced berries, but this difference alone was not enough to justify the extra expense involved in the preparation of the fruit.

Comparison of Fresh and Frozen Fruit

Fresh fruit is usually considered the best possible source of fruit flavor. Though fresh fruit ice creams in season always have a strong sales appeal, yet it is by no means proved that preserved fruits may not surpass the fresh in suitability.

Comparisons were made between fresh fruit which was mixed with sugar and immediately used in ice cream and fruit of the same variety and similarly prepared but held for 24 hours at 40° F. That which was held 24 hours before use in ice cream imparted considerably more fruit flavor. During the holding period the sugar syrup, through osmotic action, extracted much of the flavor from the fruit. This resulted in a finer flavored ice cream. The same action occurs in frozen fruit packed with sugar. Frozen fruit held for one year at 10-15° F. was found to be a satisfactory substitute for the fresh. When ice cream samples of both were compared, only the more discriminating judges could differentiate between those flavored with frozen fruit and with fresh fruit.

The Amount of Fruit to Use in Ice Cream

The percentage of fruit used affects not only the flavor of ice cream but the body and texture and rate of freezing as well. Therefore this factor should receive careful consideration by the manufacturer.

Strawberry ice cream was made, using from 6 to 20 per cent of fruit. The ice cream became progressively more desirable in flavor up to about 15 per cent. Above 15 per cent, very little increase in fruit flavor was detected, and a coarsening and weakening of the texture and body of the ice cream was evident. These defects actually detracted somewhat from the flavor because the product deteriorated more rapidly in storage than the ice creams containing less fruit.

The concentration of sugar and other soluble solids was also increased in proportion to the amount of fruit used. This resulted in weak-bodied ice cream, which was soft at ordinary cabinet temperatures, if more than 15 per cent of frozen fruit of the 2:1 ratio were used.

The data in Table 8 show the effect of the amount of fruit upon the freezing properties of strawberry ice cream. Increasing the fruit to about 15 per cent was

TABLE 8.—THE EFFECT OF DIFFERENT AMOUNTS OF FRUIT ON THE FREEZING PROPERTIES OF STRAWBERRY ICE CREAM.

Time in Freezer Minutes	Overrun, Per cent				
	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
2	27	28	23	24	23
3	38	38	35	36	36
4	47	49	49	47	46
5	55	56	58	57	54
6	63	66	67	65	62
7	72	74	82	79	73
8	88	89	98	96	87
Brine on, minutes	6.25	6.0	5.5	5.5	6.0
Drawing temperature, degrees F.	24.0	23.8	23.7	23.6	23.5
Mix, pounds	45	40	38.5	37.5	36.5
Fruit, 2 : 1 pack, pounds	0	5	6.5	7.5	8.5
Fruit, per cent	0	11.11	14.44	16.66	18.88

accompanied by an increase in the rate of overrun incorporation, but larger amounts of fruit resulted in a slight decrease. The rate of cooling in the freezer was increased by the addition of fruit, which is shown both by the drawing temperatures and by the length of time the brine was used (Tables 8 and 9). Fruit ice creams cooled more rapidly and whipped faster during freezing than plain ice creams. This is assumed to be due to the lowering of the viscosity of the mix by partial coagulation of casein by the fruit acids, as well as to the dilution effect.

TABLE 9.—FREEZING DATA FOR VANILLA, STRAWBERRY, RASPBERRY, AND PEACH ICE CREAM MADE FROM THE SAME BASIC MIX.

Time in Freezer Minutes	Overrun, Per cent			
	Vanilla	Strawberry	Raspberry	Peach
2	30	23	22	23
3	39	35	33	33
4	45	41	39	38
5	49	49	47	45
6	55	58	56	52
7	65	68	70	62
8	78	83	81	74
9	86	90	93	86
10	94	100	99	96
Brine on, minutes	6.0	5.33	5.33	6.0
Drawing temperature, degrees F.	24.5	24.0	24.0	24.3
Mix, pounds	45	38.5	38.5	38.5
Fruit, 2 : 1 pack, pounds	0	6.5	6.5	6.5

Time to Add Fruit

In commercial practice fruit is added to the mix either at the beginning of the freezing process or after the mix has been partially frozen. A comparison of these two methods showed that the addition of the fruit at the beginning of the freezing process produced a more uniform distribution of fruit, a shorter freezing period, and a better flavor in the ice cream. When the fruit was added after the mix was partially frozen, the fruit remained near the front of the freezer and a large part of it was drawn off in the first half of the batch. Adding the fruit

at this time also raised the temperature of the mix, which resulted in slower freezing and whipping. The only advantage of adding the fruit after partial freezing of the mix was that slightly larger pieces of fruit were evident in the finished product.

The idea, now fairly prevalent, that adding fruit early in the freezing process will curdle the mix, is erroneous. Milk proteins do not normally curdle at the acidity of fruit ice creams (see Table 10). Furthermore, the rapid agitation inside the freezer at the time of mixing prevents the possibility of coagulation.

TABLE 10.—DETERMINATIONS OF pH VALUE IN FRUIT ICE CREAMS.

Flavor	Number of samples	Low pH	High pH	Average pH	Fruit added Per cent
Vanilla	12	5.95	6.4	6.29	0
Raspberry	1	.....	.....	5.8	13
Cherry	6	5.43	5.81	5.7	12
Strawberry:					
1 : 1 pack	9	5.69	6.02	5.85	15
2 : 1 pack	6	5.55	5.75	5.70	15
3 : 1 pack	9	5.48	5.82	5.61	15
Average	24	5.48	6.02	5.72	15

The Addition of Flavoring Extracts

Trials were made to determine whether part of the fruit could be replaced by the addition of strawberry extract. This was found to be impracticable. The majority of strawberry extracts studied did not impart a natural strawberry flavor. Only one extract of the eight studied could be used without actually injuring the flavor of the ice cream. This proved to be so mild in flavor that it was of no particular value.

About one-third the usual amount of vanilla extract used in the flavoring of vanilla ice cream may be added to strawberry. The vanilla flavor tends to cover off-flavors in the mix. The work indicated, however, that under most conditions the addition of strawberry or vanilla extract to strawberry ice cream was not justifiable.

Deterioration of Strawberry Ice Cream

It was observed that strawberry ice cream acquired a storage or rancid flavor in a shorter storage period than vanilla. Wright (22) showed that acidity is a factor in increasing the rate of oxidation of butter fat. Table 10 contains the average pH readings of the different fruit ice creams. The addition of the fruit increased the hydrogen ion concentration of the mix, which would thus increase the rate of oxidation of the fat. By shifting the pH of plain mix to this extent by the addition of pure lactic acid, a more rapid deterioration of the product was observed.

Tracy concludes (16) that the enzymes in the fruit itself play a part in flavor deterioration. He reported data to show that by heating the strawberries to a temperature of 175° F. for 20 minutes the enzymes were inactivated and the keeping quality of the ice cream was enhanced. This study supports the conclusions of Tracy. Dahle (4) concludes that dissolved copper salts play a part in the oxidation of butter fat in strawberry ice cream.

From the work cited above and the results secured in this study, the conclusion may be drawn that the more rapid deterioration in flavor of strawberry

ice cream is caused largely by more rapid oxidation of the butter fat which is induced in turn by the more acid nature of strawberry ice cream, the enzymes contained in the fruit, and the presence of metallic salts.

Raspberry Ice Cream

Less fruit appeared to be desirable in making raspberry ice cream than with other fruit flavors. Three reasons were evident: the seeds were objectionable when a liberal amount of fruit was used; the fruit is relatively expensive; and raspberry extracts of good quality, which could be used to replace some of the fruit, were found to be commercially available.

Much more satisfactory results were secured when either the fresh or frozen fruit was pureed to remove about 75 per cent of the seeds. From 12 to 15 per cent of the raspberry puree was necessary to properly flavor the ice cream. A product of good quality was made by reducing this amount to about 10 per cent and using it in combination with a good commercial raspberry extract.

Raspberry packs of 2:1 and 3:1 ratios proved superior to all others (see Table 5). The preference between these ratios was in favor of the 3:1 fruit in most cases. A marked difference was found between the desirability of different varieties, Cuthbert, Herbert, and St. Regis being preferred in the order named over such varieties as Newman, Latham and Ontario. The latter varieties produced an ice cream which lost its good flavor during storage more rapidly than that flavored with Cuthbert, Herbert, or St. Regis varieties. The St. Regis is a more seedy variety than either Cuthbert or Herbert.

The data in Table 9 show that raspberry ice cream cools faster in the freezer and whips faster than vanilla.

Peach Ice Cream

Peach ice cream has a popular appeal during the fresh peach season. However, a good peach flavor was found to be difficult to secure in ice cream because of the mild flavor of the fruit. Therefore, a large amount of fruit, 15 to 20 per cent, must be used. A ratio of three parts of fruit to one of sugar in frozen-packed peaches should be used. This ratio imparted the best flavor and had the added advantage that the firmness of the ice cream was not decreased as much as with the 2:1 pack. This factor is of especial importance since more fruit is necessary than for other fruit flavors.

It was found that yellow-fleshed peaches were superior to the white for flavoring ice cream and, since they are firmer, larger shreds of the fruit were evident in the ice cream. No variety of peach was studied, however, which yielded sufficient flavor. Therefore some type of flavoring extract should be added to the ice cream along with the fruit. The best product studied was a peach brandy syrup. Some manufacturers replace about one-third of the peaches with apricots and claim good results.

Canned pulped Georgia peaches (some skin was present in the fruit) were compared with fruit grown in the college orchards. The pulped fruit imparted a more desirable flavor to the ice cream. More yellow shreds of fruit were visible in the pulped product and this also improved the appearance of the ice cream.

The freezing time for peach ice cream, as is shown in Table 9, was about the same as for vanilla.

Cherry Ice Cream

The sour varieties of cherries were found to be superior to others for use in ice cream. Montmorency, Early Richmond, and May Duke cherries were

better varieties than the Morello (see Table 7). However, these cherries did not impart as satisfactory a flavor as maraschino processed cherries. By the addition of a good commercial cherry extract, or a small amount of benzaldehyde or oil of bitter almonds, to frozen fruit of the above varieties, a satisfactory substitute for the flavor of maraschino processed cherries could be secured. One to two cubic centimeters of benzaldehyde or oil of bitter almonds was sufficient for ten gallons of finished ice cream.

Cherries packed in the ratio of two pounds of fruit to one of sugar were found to be more satisfactory than packs of other ratios. A desirable amount of fruit to use in cherry ice cream was from 12 to 15 per cent. The addition of cherry extract may be practiced, as it was found that many of the extracts, if used in satisfactory amounts, were capable of improving somewhat the flavor of the cherry ice cream. The freezing time for cherry ice cream was found to be slightly less than for vanilla.

Pineapple Ice Cream

A comparison of pineapples which were packed in Hawaii and Puerto Rico was made. The fruit had been crushed and canned (heat preserved). The Hawaiian packs were found to impart a more noticeable pineapple flavor to ice cream, and possessed the added advantage of firmer flesh, a deeper color, and less syrup. The heat-preserved pineapples were found to be as satisfactory as the frozen fruit for flavoring ice cream.

From 12 to 15 per cent fruit was found to be the most desirable amount for pineapple ice cream. Pineapple ice cream was found to whip very rapidly during freezing, probably due to the partial coagulation of casein by the acid in the fruit.

General Discussion of Fruit Ice Creams

In the use of frozen or cold packed fruits, a trend is in evidence towards the 3:1 pack rather than the 2:1. Where syrup packed fruit has been used, that containing a 40 per cent sugar syrup seems more suitable than any other. This corresponds more nearly in sugar content to the 3:1 than to the 2:1 pack. This trend seems reasonable in view of the fact that the 3:1 pack contains $8\frac{1}{3}$ per cent more fruit than the 2:1. Hence more fruit flavor should be secured from the use of the 3:1 pack.

Another and perhaps more important consideration is that the 3:1 pack adds less sugar to the mix than the 2:1, and therefore an ice cream results which is firmer at the usual cabinet temperatures. This is a point of considerable importance, since the tendency in recent years has been to increase the amount of fruit, due perhaps to a corresponding decrease in the cost of the frozen fruit.

No ice cream maker should be without a hydrometer for determining the soluble solids content of fruit juices. The percentage of soluble solids in the syrup of frozen fruit is shown in Table 2 to be 38.2 for the 2:1 packs, and 32.3 for 3:1. Some frozen fruit sold on the market labelled as 3:1 was found actually to be 2:1, according to the soluble solids content of the syrup.

The freezing data which have been previously discussed indicate that fruit ice creams usually attain overrun in the freezer more rapidly than vanilla. The authors realize that this is not in agreement with the data (5) and statements (15, 14) found in previously published material on the subject. However, the data in Tables 8 and 9 are representative of that secured with two direct expansion freezers and four brine freezers, working in three different plants. The fact that slower whipping for fruit ice cream has been reported by other investigators

may be due to one or more of the following reasons: (1) the fruit used may have been at a higher temperature than the mix (particularly if frozen fruit were heated in order to hasten melting); (2) overloading the freezer may have resulted by adding the fruit to the same amount of mix that was used for vanilla ice cream; or (3) the fruit may have been added to the mix after it was partially frozen, thus raising the temperature of the entire batch and causing a loss of overrun.

Fruit ice creams should be drawn from the freezer at about 0.5° F. colder than vanilla. This is necessary in order to secure the same degree of firmness, due to the higher sugar content of the fruit ice creams, which lowers the freezing point.

Many manufacturers and consumers prefer to see large pieces of fruit scattered through fruit ice creams. The addition of the fruit at the beginning of the freezing process, as has been recommended in this bulletin, causes the fruit to be ground into small pieces, while addition of the fruit when the mix is partially frozen does not permit uniform distribution through the batch. Therefore, in order to have larger pieces of fruit visible in the ice cream, a few manufacturers follow the practice of holding out a part of the fruit pulp and adding it slowly through the fruit hopper as the ice cream is being drawn from the freezer.

The cost of flavoring fruit ice cream is not as great as one would assume when it is realized that overrun is secured on the fruit and syrup as well as the mix. Some fruits, such as frozen strawberries, canned pineapple, and bananas, do not differ greatly in cost from the ice cream mix itself. However, fruit preparations such as orange-pineapple, frozen pudding, and mint-pineapple are relatively more expensive.

Fruit Ices

Fruit ices were made from a base of 33 pounds of water, 9 pounds cane sugar, 3 pounds cerelose, and enough gelatin to cause a slight thickening in 24 hours of aging. This was found to be 0.5 per cent for the gelatin used in this experiment. To this was added 8 to 10 pounds of fruit and enough of a 50 per cent solution of citric or tartaric acid to produce an acidity of 0.7 per cent. The ices were frozen to a firm condition in the freezer and were drawn at an overrun of 30-35 per cent. Sherbets were made in the same way by substituting whole milk for the water.

Pureed raspberries, pulped peaches, strawberries, plums, and pineapple proved very satisfactory for ices. Frozen, pulped cranberries with sugar (2:1) as well as pulped, cooked cranberries also proved satisfactory. Ices were made from pulped currants which had been frozen with the 2:1 ratio, rhubarb pulp packed 1:1, blueberry and blackberry pulps packed 2:1, all of which possessed the characteristic flavor.

A study was made to determine the optimum acidity that an ice should possess. Variations in acidity from 0.5 to 1 per cent (expressed as lactic acid) were employed. The majority of judges preferred an acidity of about 0.7 per cent, the others being about equally divided between 0.6 and 0.8 per cent.

Acidity was determined by titrating a 9-gram sample of the ice (seeds and pulp excluded) with one-tenth normal sodium hydroxide, using phenolphthalein as the indicator. The weighed sample was diluted with 9 cubic centimeters of distilled water previous to titration in order to have a more workable sample. The readings were expressed in terms of lactic acid, using the formula:

$$\frac{\text{c.c. of 0.1 N NaOH used} \times 0.009 \times 100}{\text{wt. of sample in grams}} = \%\ \text{lactic acid}$$

Although many ices are colored pink, no difficulty was encountered in determining the end point because the solution became practically colorless before the

end point was reached. This method of titrating ices or sherbets for acidity is therefore recommended because the equipment is always available in an ice cream plant.

SUMMARY

Investigations on methods of freezing and utilization of frozen New England fruits were carried on during three crop seasons. All the fruits studied were grown in the college orchards, frozen, defrosted, examined, and later utilized in frozen dairy products. In all, over 650 one-gallon cans of these fruits were frozen.

1. Fruit varieties vary greatly in their suitability for freezing and for use in ice cream. Of the 20 varieties of strawberries, the most desirable frozen packs were Howard Supreme, King Edward, Marshall, Howard 17, First Quality, Aberdeen, Boquet, Beacon and Bliss. The red-fleshed varieties of strawberries gave higher colored frozen packs. The most satisfactory raspberry varieties were Cuthbert, Herbert and St. Regis; peaches, Hiley, Elberta, Hale and Crawford; cherries, Montmorency. In general, yellow-fleshed varieties of peaches were more attractive than white when frozen.

2. While plums, red currants, nectarines, cranberries, blackberries, blueberries, black and purple raspberries, and rhubarb were successfully preserved by freezing, these fruits cannot be considered entirely satisfactory. Though not suited for use in ice cream, fairly satisfactory ices can be made from them. Cranberry ice is particularly good.

3. For one-gallon cans of fruit a freezing temperature of 0 to −10° F. with subsequent storage at 10 to 15° F. proved entirely satisfactory. A moderately constant storage temperature is essential for maintaining the quality of the pack. Defrosting and refreezing are definitely injurious to both appearance and flavor of frozen fruits.

4. The soluble solids content of 20 varieties of strawberries varied from 5.9 to 7.6; acidity (citric) from 0.9 to 1.43 per cent; ratio of fruit to syrup in the 2:1 frozen pack from 1:0.62 to 1:1.46: and Brix readings from 33 to 44 per cent.

5. The sugar concentration (Brix reading) of the syrup of defrosted fruits serves as an index of the original fruit to sugar ratio. (See Table 2).

6. Discoloration in frozen fruits is normally limited to the surface layer Although this injures somewhat the appearance of the fruit, little injury to flavor results. Peaches were particularly subject to surface discoloration. Syrup packing reduced this defect considerably; vacuum sealing practically eliminated it.

7. In every case the addition of sugar to fruit before freezing greatly improved the flavor, color and general appearance of the pack. Fruit to sugar ratios of 2:1, 2.5:1, and 3:1 were most satisfactory for frozen strawberries and raspberries. When the ice cream mix contained 15 per cent sugar or less, the 2:1 or 2.5:1 packs should be used; while the 3:1 ratio was preferred when the sugar in the mix exceeded 15 per cent. Cherries should be frozen with sugar in the ratio of 2:1, and peaches with a 3:1 ratio.

8. Cerelose (corn sugar) was unsatisfactory in frozen fruit because it injured the flavor and texture and caused discoloration of the fruit.

9. Freezing fruit in syrup containing 40 or 50 per cent cane sugar proved a desirable method of storing fruit for later use in ice cream.

10. Vacuum packing prevented oxidation of the fruit at the surface, but otherwise was the equivalent of syrup or dry sugar packs.

11. Delayed freezing caused some shrinking of the fruit but did not injure the quality of the pack, providing the delay was not sufficient to allow fermentation. Pre-cooling of the fruit or syrup before freezing greatly hastened the freezing process.

12. Slicing or crushing strawberries before freezing was of no particular benefit when the fruit was used in ice cream.

13. The optimum amount of fruit of any desirable pack to use in ice cream was about 15 per cent by weight for strawberries, cherries or pineapple, 10 to 12 per cent for raspberries, and 15 to 20 per cent for peaches.

14. The time necessary to attain the desired consistency and yield in freezing ice cream varied with the flavor; the time required for peach was about the same as for vanilla, but for strawberry, pineapple, cherry and raspberry it was less.

15. The fruit should be added to the freezer immediately after the freezing operation is started if uniform fruit distribution and rapid overrun incorporation are to be realized.

16. Supplementing fruit with fruit extracts in flavoring ice cream was of no value with strawberry because most strawberry extracts had an artificial unnatural flavor. However, many raspberry, cherry, and peach extracts, when used in the correct amounts, did improve the flavor of the ice cream.

17. Strawberry ice cream deteriorated more rapidly in flavor than vanilla, due in part to more rapid oxidation of the butterfat, which is induced by the fruit acids and enzymes. Heating the fruit to 165° F. for 20 minutes inactivated the enzymes and improved the keeping quality of the ice cream.

18. A basic formula is given for fruit ices. The acidity of fruit ices should be constant, 0.7 per cent being suggested as the most desirable acidity.

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Publication of this Document Approved by Commission on Administration and Finance

4M-8-32 No. 6152

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 288 OCTOBER, 1932

The Relation of Feather Pigmentation to Intensity of Laying in Rhode Island Reds

By F. A. Hays

Deep rich plumage color and high winter laying intensity in Rhode Island Reds are desirable characters which can be influenced by breeding. This investigation was undertaken to determine to what extent both of these characters can be developed simultaneously by the breeder.

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THE RELATION OF FEATHER PIGMENTATION TO INTENSITY OF LAYING IN RHODE ISLAND REDS

By F. A. Hays

INTRODUCTION

Experience of exhibition breeders of Rhode Island Reds indicates that in order to develop the deep rich color now demanded in both sexes a considerable period of time is required before sexual maturity is attained. In other words, if pullets and cockerels become sexually mature at six or seven months they are likely to show a lighter shade of plumage than the Standard requires.

In the spring of 1915, thirty-two high-class exhibition Rhode Island Red pullets were hatched and reared at the Massachusetts Agricultural Experiment Station along with the birds being bred for high fecundity. These thirty-two pullets had an average age of 291 days when they laid their first egg while eighty-nine production-bred birds hatched and reared with them showed an average age of 253 days when they began to lay.

In the spring of 1929 a group of thirty-nine excellent exhibition pullets was hatched and reared with chicks bred for egg production. The average age at first egg was 291 days for the exhibition pullets and 197 days for 507 production pullets.

A tendency for the production-bred stock to be deficient in color was observable as early as 1915 while in 1929 practically all stock was deficient in color and some approached buff and others carried pronounced black mottling. Smut in under-color was not common.

Exhibition stock studied in 1915 was less deeply pigmented than the present-day Rhode Island Red. The stock hatched in 1929 approached the bay shade of Ridgway (1912). A rather large proportion of the birds carried smut in under-color as well. Under-color varied in shade, but the fluff was far more intensely pigmented than in the production-bred birds.

Martin (1929) has definitely shown with Barred Plymouth Rocks that exhibition color is associated with slow maturity and his data indicate a probable correlation between exhibition plumage color and low intensity.

There is definite need for experimental evidence on the relation of degree of pigmentation in Rhode Island Reds to intensity of laying. Winter intensity has been shown by Hays and Sanborn (1927) to be rather intimately associated with annual production. The Standard of Perfection (1930) calls for rich red plumage color in both males and females, making dark plumage color of economic importance. It would seem desirable, therefore, from the breeder's standpoint to combine exhibition plumage color with high intensity.

The experiment reported below began with two foundation groups of birds hatched in 1927. The first group consisted of forty-eight pullets selected for very light adult plumage color. The second group was made up of forty-nine pullets selected for dark plumage color. Both groups came from the flock that had been bred for high fecundity since 1913. Generations two, three and four were hatched the following years. The selection of breeders each season was on the basis of very light and very dark plumage. All birds were pedigreed, females were trap-nested for a full year, and both male and female progeny were described for plumage color at the age of about six months.

Plan of Matings

In the spring of 1928, four unrelated females from the light-colored foundation were mated to an unrelated, light-colored cockerel. From the dark-colored foundation, two pairs of sisters unrelated and a third unrelated pullet were all mated to a selected unrelated dark-colored cockerel.

In 1929 the breeding stock in the light line consisted of three full sisters mated to their half-brother. The breeders in the dark line were two pairs of half-sisters mated to their half-brothers.

The 1930 breeding stock in the light line consisted of two half-sisters mated first to their uncle and later to the male used in this line in 1929. The dark group contained two full-sisters mated to their uncle.

PLUMAGE COLOR IN THE DIFFERENT GENERATIONS

1928 Breeders

In the light-colored line, offspring were retained from four females with the following color description:

H993—Orange hackle, medium red surface color except for a dark salmon breast, light under-color free from smut.

H1076—Medium red hackle, medium red surface except for a dark salmon breast, light under-color with a slight amount of smut.

H1106—Orange hackle, very light red surface color, salmon breast, very light under-color free from smut.

H1270—Orange hackle, medium red surface except for dark salmon breast, light under-color free from smut.

Male H3515—Orange hackle, very light red surface color and under-color, no smut.

The dark-colored line came from five females and a male described as follows:

H1154—Orange hackle, medium red surface except light in breast, light under-color with smut.

H1156 (full sister to H1154)—Orange, black-ticked hackle; dark red surface color; rather light under-color with smut.

H1293—Orange, black-ticked hackle; dark red surface color mottled with black; light under-color with smut.

H1459—Medium red surface color and medium under-color with only a trace of smut.

H1460 (sister to H1459)—Orange hackle, medium red surface color except for light breast, light under-color free from smut.

Male H3164—Dark red hackle, dark red surface color, under-color somewhat light but free from smut.

1929 Breeders

In the light-colored line the plumage color is described as follows:

I733—Light red surface color, light under-color, free from smut.

I1226—Medium surface color, medium under-color, free from smut.

I1782—Light red surface color, light under-color, free from smut.

Male I1206—Very light surface color and very light under-color without smut.

In the dark-colored line the descriptions follow:

I1230—Medium surface color, very light under-color, free from smut.

I1261—Medium dark surface color, light under-color and no smut.

I1845—Dark surface color, medium under-color, no smut.

I2383—Near standard color, medium under-color, free from smut.

Male I389—Near standard surface color, medium under-color and no smut.

1929 Offspring

The males and females hatched in the two lines in 1929 may be roughly grouped for surface plumage color as follows:

TABLE 1.—PLUMAGE COLOR.

Color	Light Line		Dark Line	
	Males	Females	Males	Females
Very light	2	2	0	0
Light	24	20	11	0
Medium	3	6	27	7
Dark	0	0	4	14
Standard	0	0	0	2
Total	29	28	42	23

The tendency of the males to appear in a lighter plumage class than their sisters is noticeable in the dark line, while there is no significant difference in grouping of males and females in the light line.

1930 Breeders

Two hens were used as breeders in the light line in 1930. They were described as follows:

J1503—Light orange, black-ticked hackle; light red surface; light under-color and no smut.

J2681—Light orange, black-ticked hackle; medium light red surface color; medium under-color, somewhat mottled but no smut.

Male I246—Very light in color.

Male I1206—Very light surface color, very light under-color, no smut.

In the dark line only one female was used as a breeder. She is described as follows:

J544—Orange, black-ticked hackle; dark red surface; medium under-color and no smut.

Male H3164—Dark black-ticked hackle, medium dark red surface, medium under-color, no smut.

1930 Offspring

Using the same grouping for color as was applied in 1929, the 1930 progeny were classed as follows with respect to plumage color:

TABLE 2.—PLUMAGE COLOR.

Color	Light Line		Dark Line	
	Males	Females	Males	Females
Very light	1	0	0	0
Light	4	6	0	0
Medium	2	5	0	6
Dark	0	0	1	3
Standard	0	0	0	0
Total	7	11	1	9

The number of offspring in the last generation is very small. This is due to decreased egg production reducing the number of breeding females selected,

probably intensified by inbreeding. There is still considerable overlapping in the two lines in the medium color-group, and the tendency for males to show lighter plumage color than their sisters still persists.

TABLE 3.—MEAN HATCHABILITY AND ANNUAL PRODUCTION OF THREE GENERATIONS.

	Mean Hatchability, Per Cent		Annual Egg Production	
	Light Line	Dark Line	Light Line	Dark Line
1928	58.5	69.8	229	218
1929	78.7	73.0	197	206
1930	83.0	50.0	197	180

The foundation group of light-colored birds includes 29 individuals with complete annual egg records. The mean for this group is 188 eggs, while the foundation dark-colored group including 33 birds averaged 184 eggs. This difference of four eggs is not statistically significant.

Hatchability of breeding females varied widely and not consistently in the three seasons reported.

Annual egg production showed a significant decrease on successive generations as might be anticipated as a concomitant of inbreeding.

PLUMAGE COLOR AND WINTER INTENSITY

The foundation females in the light and dark lines may be roughly classed into five groups with respect to surface plumage color of back. The accompanying table gives the number of individual birds in each group and the mean winter clutch size of the group. It will be observed that the light and dark lines overlap in the medium group and that the mean clutch size in this group in the two lines is essentially the same. A consistent decrease in winter clutch size with increased color is observable in all classes with a significant number of birds. The fact should be mentioned in this connection that the two individuals with the extremely large clutch size of 10.5 and 10.6 respectively, are in the very light group. One individual of the dark line in the medium group showed a clutch size of 9.3.

Foundation Females—1927

TABLE 4.—SURFACE PLUMAGE COLOR OF BACK AND WINTER CLUTCH SIZE.

Color	Light Line		Dark Line	
	Number	Clutch Size	Number	Clutch Size
Very light	29	3.73	0	.....
Light	13	2.75	1	1.7
Medium	6	3.57	23	3.46
Dark	0	.....	19	3.19
Standard	0	.....	4	2.58
Total	48		47	

1928 Generation

Complete records on plumage color of the progeny hatched in 1928 are not available for study. Consequently, the relation of plumage color and clutch size cannot be considered.

1929 Generation

A total of 55 pullets is available in the 1929 generation. These are classified into five color groups and the mean clutch size of the groups recorded in Table 5.

TABLE 5.—PLUMAGE COLOR AND CLUTCH SIZE.

Color	Light Line		Dark Line	
	Number	Clutch Size	Number	Clutch Size
Very light	2	3.75	0	.....
Light	24	3.00	0	.....
Medium	6	2.71	12	3.03
Dark	0	...	9	2.44
Standard	0	...	2	2.25
Total	32		23	

These data are consistent, for an increase in degree of plumage color is regularly followed by a decrease in clutch size.

1930 Generation

Table 6 shows the same consistent relationship between clutch size and degree of pigmentation as in previous generations. There is some evidence of increased intensity in the dark line, and there is a tendency for medium shade birds in the dark line to excel medium shade birds in the light line, especially during the last two generations of this experiment.

TABLE 6.—PLUMAGE COLOR AND CLUTCH SIZE.

Color	Light Line		Dark Line	
	Number	Clutch Size	Number	Clutch Size
Very light	0	.....	0	.....
Light	8	5.44	0	.....
Medium	3	2.87	7	3.79
Dark	0	.....	1	2.40
Standard	0	...	0	.....
Total	11		8	

Table 7 shows that the mean age at sexual maturity was slightly greater in the dark line in all generations after the first. Mean winter clutch size of the dark line was also below the light line in all generations. In mean winter production the light line surpassed in all generations, except the last. In general the data show some superiority of the light line over the dark line in winter intensity. The superiority of the light line over the dark line in annual egg production is not statistically significant in any generation and the light line cannot be considered superior from the standpoint of fecundity.

TABLE 7.—MEAN AGE AT FIRST EGG, MEAN WINTER CLUTCH, MEAN WINTER PRODUCTION, AND MEAN ANNUAL PRODUCTION IN TWO LINES THROUGH FOUR GENERATIONS.

Generation	Age at First Egg	Winter Clutch	Winter Production	Annual Production
		Light Line		
1	183.8 ± 2.64	3.7 ± .30	88.8 ± 2.53	188.1 ± 5.46
2	193.7 ± 2.83	3.8 ± .18	93.4 ± 2.78	228.6 ± 4.88
3	186.7 ± 2.68	3.3 ± .18	86.1 ± 3.22	197.3 ± 4.61
4	189.2 ± 5.26	4.3 ± .16	88.8 ± 6.36	196.8 ± 6.04
		Dark Line		
1	179.9 ± 2.09	3.4 ± .19	82.8 ± 2.87	184.2 ± 5.17
2	198.0 ± 2.55	3.7 ± .13	84.3 ± 2.69	217.9 ± 5.36
3	194.2 ± 3.48	2.7 ± .16	73.9 ± 4.14	206.4 ± 5.26
4	198.0 ± 4.92	3.1 ± .29	92.2 ± 3.36	180.2 ± 5.74

GENETIC RELATION OF WINTER INTENSITY AND RHODE ISLAND RED COLOR

Since exhibition Rhode Island Reds are slower maturing than production-bred birds, it is possible that sexual maturity checks the intensification of pigment. The difficulty of measuring such a physiological effect is apparent, however. There is also evidence that early sexual maturity does not always prevent the development of the deep shade of pigment desired. The genetically late-maturing birds in the light group showed even a smaller mean clutch size than the late-maturing birds in the dark group. The number of birds concerned in both lines, however, is small.

The eight smutty birds in the original foundation had a mean clutch size of 3.1 which does not indicate that gene E, responsible for smut in under-color, is linked with gene I for medium clutch size.

Extreme clutch sizes of four or more were equally numerous in both the light and the dark lines of the foundation stock.

Since the population used carried but a very small proportion of genetically late-maturing birds, it is not possible to adequately study the relation of surface color to late sexual maturity. A group of 31 exhibition pullets hatched and reared in 1929 consisted of 30 genetically late and 1 genetically early. The single early individual had a clutch size of 2.4 and there were three birds in the late group with clutch sizes equal to or greater than this. The mean winter clutch size of the 30 late-maturing birds was 1.4. These data suggest that deeply colored birds are likely to be deficient in winter clutch size.

In general, the data obtained in this experiment show that large clutch size is a little less common in the dark birds but that the birds with medium shades of red average high in clutch size in both the light and the dark lines. It seems probable, therefore, that the genetic make-up necessary for very dark plumage color is such that a long developmental period previous to sexual maturity is necessary. Since early sexual maturity is rather intimately correlated with large winter clutch size, a large proportion of deeply colored birds might be expected to exhibit low intensity. In view of this fact, it would seem to be a laborious process to establish uniform deep pigmentation and high intensity in a flock, but a medium shade of red should be maintained without difficulty. Care should be taken to select as breeders only birds homozygous for gene B and at the same time showing a winter clutch mean of three or more.

SUMMARY

Light and dark-colored lines of Rhode Island Reds were carried through four generations to discover possible relations between intensity of laying and degree of feather pigmentation.

Age at sexual maturity was slightly greater in the dark line.

Winter clutch size was smaller in the dark line in all generations.

The gene for smut appears to be independent of the genes for high winter intensity.

The data show indirectly that deep plumage color occurs generally in slow-maturing birds and that a developmental period greater than 215 days from hatching to sexual maturity is required for the development of the deep shade of pigment now demanded in exhibition Rhode Island Reds.

There is evidence that a medium shade of red is often accompanied by high winter intensity.

Overlapping in shade of color frequently occurred between the darker individuals of the light line and the lighter individuals of the dark line.

Annual egg production was not significantly different in the two lines in any generation.

Results of this experiment indicate that a medium shade of red is more typical of a Rhode Island Red flock bred for high fecundity than a very dark or a very light shade.

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Publication of this Document Approved by Commission on Administration and Finance

3M 10-'32 No. 6703

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 289 DECEMBER, 1932

Hereditary and Environmental Factors Affecting Variability in Egg Production

By F. A. Hays

It is generally conceded that the egg production of fowls is influenced by heritage and environment. There are, however, many factors that contribute to these influences, and it should be of scientific interest and economic importance to evaluate some of them. This investigation and the results reported here constitute such an attempt.

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HEREDITARY AND ENVIRONMENTAL FACTORS AFFECTING VARIABILITY IN EGG PRODUCTION

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

It is a well-known fact that both hereditary and environmental influences affect the number of eggs laid by a hen. Evidence is not conclusive on many points, however, and experimental data have not been reported to furnish information concerning the quantitative variation of specific fecundity traits from generation to generation. There is at present an outstanding need of a clear-cut distinction between the effects on fecundity of heritage and environment. Such a problem offers many difficulties, the most outstanding of which is the lack of any measure of fecundity in males.

This report concerns itself with results obtained in carrying three lines of birds through four generations. Consideration is given to variability in five inherited fecundity characters; sexual maturity, intensity, winter pause duration, total days broody, and persistency.

The variability in winter and annual egg records is also reported. Such environmental influences as hatching date, increase or decrease in body weight, and daily house temperature are considered in relation to egg production and the relative importance of each is discussed.

PLAN OF EXPERIMENT

1928 Matings

In the spring of 1928 three pens of yearling hens were selected for this experiment. Pen A consisted of six hens from three unrelated families mated to an unrelated yearling male. The breeding females and the male were chosen with special reference to uniformity within the family for age at first egg, length of winter pause, intensity, days broody and persistency.

Pen B contained two unrelated yearling hens. These two hens came from families that were especially uniform in annual egg records. The male used in this pen was a half brother to one hen and not related to the other. His sisters were very uniform in annual egg records.

Pen C included four yearling hens from three families that had very high annual egg records. Three of the hens were half-sisters and the fourth was unrelated. These half sisters were mated to their half brother and the unrelated hen was not related to this male.

1929 Matings

Selection of breeding stock in 1929 to produce generation three in Pen A was on the basis already indicated, of family uniformity in the second generation of this line. Since pullet breeders were used, it was only possible to consider in selection, age at sexual maturity, intensity and winter pause. The male was

a yearling and was chosen according to stipulations for line A. Two of the pullet breeders were not related to the male and one was his half sister.

The 1929 selection for line B consisted of two pullets, half sisters to each other, selected from the previous generation. A yearling male from the preceding generation and unrelated to the pullets was mated to them.

Pen C in 1929 contained two full sisters and these were mated to a yearling male of the previous generation but unrelated to them.

1930 Matings

In line A for the 1930 matings, four pullets were bred from. Three of these were half sisters to the cockerel used and one was his full sister.

Line B was made up of four pullet sisters mated to their full brother.

Line C carried one pullet mated to a cockerel. These birds were full brother and sister.

In all cases where pullet breeders were made use of, selection of breeders was limited to the characters of early maturity, winter pause and intensity, or to egg production during the early months of the laying year. In this experiment the most definite selection on the basis indicated was made on the parental generation where all birds were yearlings. All birds were pedigreed Rhode Island Reds.

Related Matings

The foundation stocks were hatched in 1926 and these were mated in 1928 to produce the second generation. Generations three and four were hatched in 1929 and 1930, each from the previous generation pullets.

In line A the foundation male was not related to the foundation females selected. The six females came from three unrelated families giving diversity of ancestry in this line with no inbreeding in the second generation hatched in 1928. The third generation hatched in 1929 came from three pullets mated to a yearling male. Two of these pullets were not related to the male and the third was his half-sister. There were 22 daughters produced, only four of which were from the inbred mating. The fourth generation of 23 daughters was produced by mating three pullet sisters to their half-brother and a fourth pullet half-sister to her half-brother. This last generation is rather closely bred and may be compared for variability with the first two generations which were not inbred.

In line B two foundation hens were used as breeders. They were not related to each other, one was not related to the male used and the other was his half-sister. This gave a second generation of 15 daughters, eight from the unrelated mating and seven from the related mating. The third generation of 12 daughters came from two half-sisters mated as pullets to an unrelated yearling male. The fourth generation gave 19 daughters. Sixteen of these were from full brother-sister matings and 3 from half brother-sister matings. The foundation females in line B were unrelated and there was some inbreeding in the second generation, none in the third generation and close inbreeding in the fourth generation.

Line C was founded by four yearling hens and a yearling male. Three of these hens were half-sisters representing two families and the fourth was unrelated. The male was a half-brother to the three half-sisters and unrelated to the other hen. The matings for 1929 were between two pullet full-sisters and an unrelated yearling male. The fourth generation came from a single mating of a cockerel and pullet that were full brother and sister giving only two daughters.

In general, the degree of relationship increases in successive generations. This method of breeding might be expected to reduce the amount of variability for inherited characters in the later generations. There are no reasons to assume, however, that inbreeding would reduce variability in egg records produced by environmental influences.

VARIABILITY IN HEREDITARY CHARACTERS AFFECTING FECUNDITY

The five hereditary characters—age at sexual maturity, winter intensity, winter pause, broodiness, and persistency—are known to have significant effects on the annual egg records of the flock studied. Results of breeding for three generations from three selected foundations may be studied with respect to variability in the above five characters and in winter and annual egg production. Table 1 records the coefficients of variation of the four generations in this experiment with respect to the five inherited characters and for winter and annual egg records.

The check group is made up of 1695 birds hatched in the five years from 1925 to 1929. These birds compose the general flock being developed for high fecundity and are used as checks on all records, except winter production. Flocks hatched from 1916 to 1925 including 3867 birds furnish the check coefficient of variation in winter egg production.

TABLE 1—COEFFICIENTS OF VARIATION IN CHARACTERS AFFECTING FECUNDITY AND IN WINTER AND ANNUAL PRODUCTION.

Year Hatched	Generation	Number of Birds	COEFFICIENTS OF VARIATION—PER CENT						
			Age at First Egg	Intensity	Pause Days	Broody Days	Persistency Days	Winter Production	Annual Production
				Line A					
1926	1	15	6.72	60.77	75.51	69.23	4.36	29.07	14.92
1928	2	46	11.29	35.20	67.79	0	9.74	29.08	17.16
1929	3	13	8.38	31.32	65.76	0	12.11	23.53	18.51
1930	4	23	11.79	30.10	44.49	15.56	16.07	37.24	22.41
				Line B					
1926	1	4	12.09	59.11	0	0	0	16.57	5.52
1928	2	15	9.23	27.44	63.48	0	14.22	19.45	17.28
1929	3	12	14.10	33.27	66.67	33.33	11.94	31.87	12.72
1930	4	19	12.74	48.49	80.87	75.38	14.87	33.11	19.16
				Line C					
1926	1	15	8.63	46.95	69.85	67.86	15.82	24.52	14.45
1928	2	48	10.33	28.72	65.32	41.82	12.63	27.05	13.66
1929	3	3	6.10	8.80	0	0	3.98	46.77	11.66
1930	4	2	5.14	0	0	0	4.58	11.43	2.27
				Checks					
1925-29		1695	10.64	47.65	67.57	75.94	14.41	.....	19.82
1916-25		3867	.....	.....	.....	.....	.....	41.24	.....

Age at First Egg

Line A had the lowest variability in age at sexual maturity in the first generation. The coefficients of variation in the three lines for the first generation were 6.72, 12.09 and 8.63 per cent, respectively. The variability in age increased in subsequent generations in line A and was greater in the fourth generation than the normal of 10.64 per cent shown by the check group.

Line B showed a wider variation in age at first egg than the check group in all generations, except the second. It is clearly evident that neither the method of selecting breeders nor the degree of relationship reduced the age variability in this line. In fact, 19 of the 22 daughters in the fourth generation actually came from full brother-sister matings.

Line C exhibited a very significant reduction in variability of age at sexual maturity in the last two generations. This line actually had a variability in the fourth generation about half as great as the check group. The low variability was evident in the third generation resulting from unrelated matings as well as in the fourth generation from a brother-sister mating.

In general, these data indicate that non-heritable influences are constantly operating to reduce or increase the age at sexual maturity in genetically early pullets so that a reduction in age variability below 10 per cent by breeding methods does not seem feasible. More carefully controlled environmental conditions are likely to reduce variability but the possibilities here are limited.

Intensity

Intensity is here measured by mean winter clutch size. The first generation of females in lines A and B show a variability of intensity of about 60 per cent. Line C has a variability of about 47 per cent in the first generation and is comparable with the check group. The results of breeding are shown in generations two, three and four.

Line A was selected each year for uniform high intensity. It will be observed that the clutch size showed a consistent decrease in variability with each generation and the last three generations are lower in variability than the check group.

Line B exhibited a high degree of uniformity in intensity in the second generation; but without specific selection for uniformity generations three and four show decreased uniformity.

Line C gave a highly significant decrease in variability in each succeeding generation. The number of birds concerned in the last generation is too small to give the zero value significance, however. Results in this line illustrate that in the selection of very high producers for breeding, the variability of winter intensity is reduced. It is probable that almost every bird in the first generation of this line carried both genes I and I^1 for high intensity and such a genetic make-up should produce increased uniformity in succeeding generations.

The data point in general to the effect of inheritance upon uniformity of intensity and demonstrate clearly that breeding is more important than environment in controlling variation in intensity.

Duration of Winter Pause

In duration of winter pause only birds ceasing to lay for four or more days in the winter season are considered. Such birds presumably carry the dominant

gene M. This being the case, no consistent lowering of variability in succeeding generations might be anticipated as long as controllable environmental influences remain constant.

Table 1 shows that both lines A and C were highly variable in pause duration in the first generation. The number of pause birds in line C is too small to give a value for this line.

Line A had a consistent decrease in variability for length of pause in generations two, three and four. Line B did not decrease in variability in successive generations and showed greater variability than the checks in the fourth generation. A sufficient number of birds with pause in line C occur only in the first two generations. There is no significant change of variability in these two generations.

The records on variability in pause duration in line C suggest that there may be minor hereditary factors modifying pause duration. More data are necessary before definite conclusions may be drawn.

Days Broody

The sum of the non-productive days associated with broody periods during the pullet laying year may be used as a measure of degree of broodiness. In this report only birds exhibiting broodiness in the first laying year are considered. Goodale, Sanborn and White (1920) offer a two-factor hypothesis to explain the presence or absence of the broody instinct, but the causes of variation in degree of broodiness have not been reported.

Table 1 shows a large coefficient of variation for degree of broodiness in the first generation for lines A and C. Line B included so few broody birds in the first and second generations that the variation could not be determined.

In general, there appears to be a decline in variability in degree of broodiness in two of the lines. Since breeding females were selected in each line for freedom from broodiness, it seems probable also that there may be heritable modifiers affecting degree of broodiness. Further data are being secured on this particular point.

Persistency of Laying

Persistency is a character which, like age at sexual maturity, has a relatively low variability. Generation one in lines A and B had very little variability. Line C, however, gave a coefficient of variation in the first generation amounting to 15.82 per cent, while the normal for the flock is 14.41 per cent.

In succeeding generations line A continued to increase in variability, strongly suggesting that environmental influences were operating because selection of breeders was based upon uniformity in the family.

Line B changed but little in variability of persistency in the last three generations, but there was a marked increase from the first to succeeding generations.

Line C began with high variability and there was a decrease with each generation to the very low constants of 3.98 and 4.58 per cent, respectively, in generations three and four. The probable explanation of this improved uniformity lies in the fact that very high production is not possible without high persistency, and in the selection of breeders on high annual egg records, the line approached genetic purity for persistency.

These data give evidence that in selection for uniformity in persistency in the three lines, environmental forces appear to be more potent than heredity in affecting variability in strains where most individuals carry gene P for high persistency.

To sum up, the data presented in Table 1 concerning the variability of five inherited characters affecting fecundity indicate the following: Age at first egg in pullets is modified by environmental influences in a genetically early maturing population so that there is a variation of about 10 per cent that is not produced by hereditary differences. Winter intensity is highly variable, and the response to selection for low variability in all three lines indicates that the observed high variability is largely due to genetic differences. The data further point to the possibility of reducing the variation of intensity to a figure comparable with age at sexual maturity. Winter pause duration is modified but little by selection. Some evidence that degree of broodiness is governed by hereditary factors appears. High persistency behaves like early sexual maturity in that a moderate degree of variation occurs that does not appear to be genetic.

VARIATION IN WINTER PRODUCTION

Winter production depends largely upon the three inherited characters; age at sexual maturity, winter pause and intensity. Line A was constantly selected for uniformity in the above characters along with non-broodiness and high persistency. Lines B and C were not selected for uniformity in these inherited characters. Variation in winter egg records was not consistently reduced in any of the lines, but all three lines were less variable than the check group.

VARIATION IN ANNUAL PRODUCTION

Annual egg records depend upon five inherited characters already indicated as well as upon many environmental influences both controllable and otherwise. Line A was selected for uniformity in inherited characters affecting fecundity, line B was selected for uniformity of annual egg records, and line C was selected for high egg records. All three lines were carried under the same environmental conditions.

The data in Table 1 show that line C alone decreased in variability with each generation. This fact would indicate that selection for high annual records decreased the variation in annual records. The data as a whole show that both heredity and environment are operating to affect variation in annual egg records.

ENVIRONMENTAL FACTORS IN RELATION TO VARIATION IN ANNUAL PRODUCTION

Hatching Date

Birds used in this experiment were regularly hatched in eight weekly hatches beginning March 25. It is conceivable that these rather restricted hatching dates may affect the variation in annual egg production because unequal numbers of birds in the three lines were hatched on the same date.

In Table 2 the three lines are combined and the number of individuals hatched on each date in each generation is recorded. The coefficients of variation of the mean production records of each hatch are recorded in the four generations to serve as a rough measure of variation in production attributable to differences in hatching dates.

TABLE 2—HATCHING DATE IN RELATION TO ANNUAL PRODUCTION.

(Lines A, B, and C combined.)

Hatch No.	1926 FIRST GENERATION		1928 SECOND GENERATION		1929 THIRD GENERATION		1930 FOURTH GENERATION	
	Number of Birds	Mean Production	Number of Birds	Mean Production	Number of Birds	Mean Production	Number of Birds	Mean Production
		Eggs		*Eggs*		*Eggs*		*Eggs*
1	4	218.00	26	217.65	5	238.00	9	173.89
2	5	238.40	14	221.21	4	246.50	8	204.50
3	0	.....	9	226.67	7	240.29	8	163.38
4	1	171.00	11	234.18	3	239.00	9	169.67
5	4	249.25	20	232.35	5	218.20	7	191.71
6	5	236.00	11	248.00	4	171.50	2	194.50
7	8	244.88	12	235.75	0	.....	1	225.00
8	7	241.00	6	225.67	0	.....	0	.....
Total	34		109		28		44	
Mean		237.00		228.72		226.86		181.61
	Coefficients of Variation of Means—Per Cent							
		6.06 ± .50		4.05 ± .18		10.70 ± .97		8.94 ± .64

The coefficients of variation in mean production due to differences in hatching date are recorded at the end of Table 2. These, together with the gross data presented in the table, show clearly that hatching date does affect annual production and variability in production. Hatching date also appears to have had a greater effect upon variation in the last two generations. The data indicate that about 7 per cent of the variation in annual records may be assigned to differences in hatching date.

Change in Body Weight During the Laying Year

All birds were weighed approximately 365 days after the mean date of first egg to discover how body weight behaves near the close of the laying year. The total population consisted of 149 individuals that showed a weight increase after the first pullet egg, 54 individuals that showed a loss of weight, and 2 individuals having no weight change. The mean annual egg record of the gaining group was 225.98. The mean production of the group losing weight was 211.28. Table 3 gives the detailed data.

The coefficient of variation for the twelve mean production records in the gaining group is 9.86 ± .39 per cent. The coefficient for the losing group is 11.09 ± .72 per cent. The difference is 1.23 ± .82 per cent. This difference is not statistically significant and indicates that the variation in annual production is independent of gain or loss in weight during the laying year. The data show that body weight change is not a factor affecting variability of annual egg records.

TABLE 3—BODY WEIGHT INCREASE OR DECREASE IN RELATION TO ANNUAL PRODUCTION.

Generation and Line		Birds showing increase in weight			Birds showing decrease in weight			Birds showing no change in weight		
		No. of Birds	Mean Increase	Mean Production	No. of Birds	Mean Decrease	Mean Production	No. of Birds	Mean Weight	Mean Production
			Pounds	*Eggs*		*Pounds*	*Eggs*		*Pounds*	*Eggs*
1	A	13	0.67	231.54	2	−0.71	233.00	0	.....	.....
	B	3	.31	268.67	1	−.35	279.00	0	.....	.....
	C	11	.78	233.00	4	−.42	233.50	0	.....	.....
2	A	39	.80	233.85	7	−.57	227.14	0	.....	.....
	B	9	.57	209.11	5	−.64	229.00	0	.....	.....
	C	31	.65	236.35	13	−.33	215.08	1	4.65	196
3	A	9	.61	253.00	4	−.51	209.50	0	.....	.....
	B	7	.72	225.14	4	−.28	217.00	0	.....	.....
	C	2	.59	225.50	1	−.33	177.00	0	.....	.....
4	A	13	.89	170.00	6	−.39	161.67	0	.....	.....
	B	8	.60	198.63	7	−.51	192.29	1	5.50	122
	C	1	.55	151.00	0	.....	.....	0	.....	.....
Total		149			54			2		
Mean				225.98			211.28			159
Coefficient of Variation of Means—Per Cent										
				9.86 ± .39			11.09 ± .72			

House Temperature

Graham (1930) presented data suggesting that house temperature and egg production seem to vary together. His data show in general that a fluctuation in house temperature is likely to be followed by a fluctuation in the production of the birds. Smith (1930) reported that higher house temperatures within limits increased winter egg production.

In the charts the relation of house temperature to egg production is shown. The weekly percentage production together with the mean daily house temperature are illustrated graphically for the laying years 1926-27, 1928-29, 1929-30 and 1930-31. The period begins September 11 and closes November 26 each year.

Mean house temperature readings were taken at 7 A.M. and 6 P.M. daily with thermometers located on the roost level immediately in front of the roosts. The mean daily house temperature used in the charts is the mean of the two readings.

The birds of the three lines are combined on the charts. Only those individuals that lived throughout the period each year are included in the production graph. The number of birds included each year is as follows: hatched in 1926, 34; hatched in 1928, 109; hatched in 1929, 28; and hatched in 1930, 44.

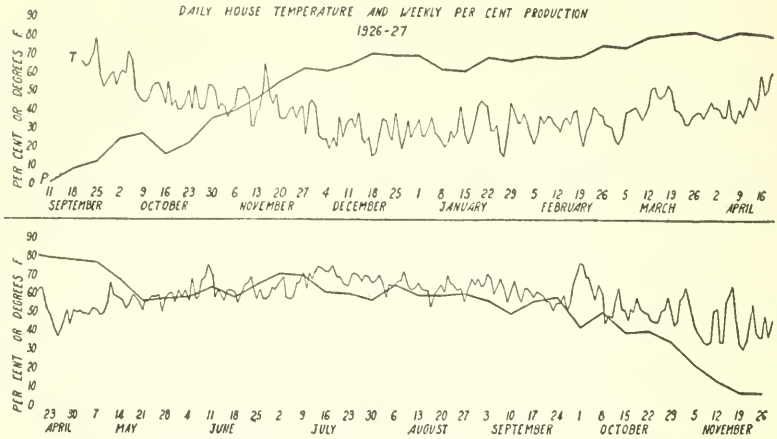

Chart 1. Relation of House Temperature to Egg Production, 1926-27.

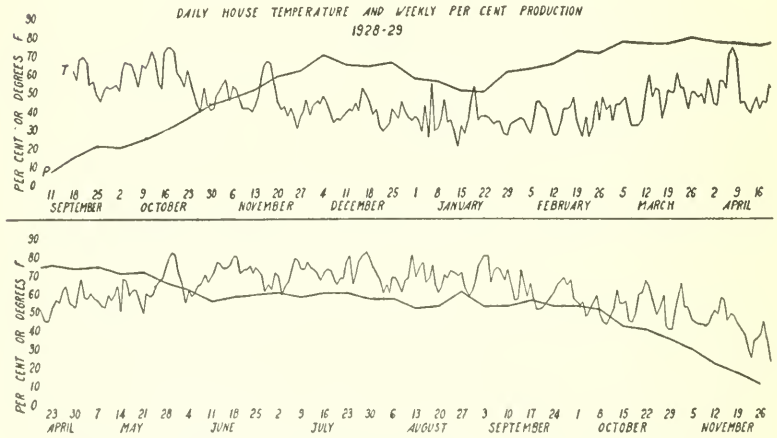

Chart 2. Relation of House Temperature to Egg Production, 1928-29.

The flocks included in the four years reported do not show any clean-cut response in production to house temperature changes. The data do indicate, however, that a house temperature near the freezing point was accompanied by decreased production in three years out of four in the month of January. In the summer season there is evidence that house temperatures above 70° react

unfavorably on egg production. Production responses to temperature changes seem to follow soon after the temperature changes. On the whole, the effects of variation in house temperature on variation in egg production are not very significant for the birds studied, and house temperature may be placed among the minor causes of variability in production.

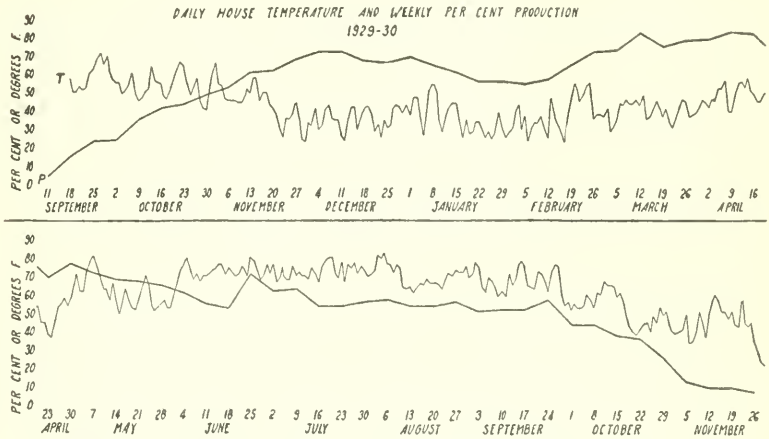

Chart 3. Relation of House Temperature to Egg Production, 1929-30.

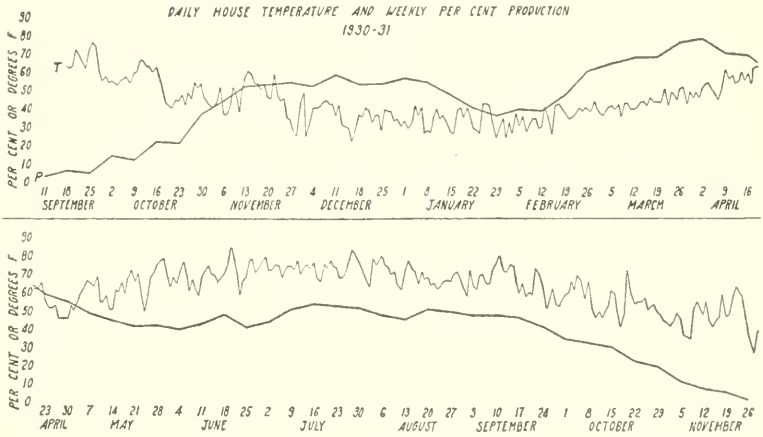

Chart 4. Relation of House Temperature to Egg Production, 1930-31

SUMMARY

Three lines were established, each on a different selection basis: Line A, for uniformity in inherited characters affecting fecundity; Line B, for uniformity of annual egg records; and Line C, for high annual records. Each line was carried through four generations to study variability of inherited characters affecting fecundity and the effect of some environmental influences upon variability in egg production.

Age at sexual maturity shows a coefficient of variation of about 10 per cent produced by environment in birds of the same genetic constitution for sexual maturity.

Winter intensity is highly variable in a flock, due to genetic differences. In this experiment the variability was greatly reduced by selection of breeders in four generations. There is no evidence to indicate that environment influences clutch size.

Winter pause duration may be reduced by constant selection and is also greatly affected by environmental influences.

There is evidence that degree of broodiness measured by total days broody may be influenced by hereditary modifiers.

Persistency shows a variation of about 10 per cent that may be ascribed to environmental influences.

Variability in winter egg production decreased only in Line C, and increased inbreeding in successive generations did not reduce the variation in winter egg records.

Variation in annual egg records was less in Lines B and C than in Line A.

Differences in hatching dates are responsible for about 7 per cent of the variation in annual egg records.

Neither increase nor decrease in body weight of the pullets during the laying year affected the annual egg records.

House temperature near the freezing point reduces egg production; house temperatures above 70 to 75° may perceptibly reduce production; and production changes are likely to follow soon after temperature changes.

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3M 12-'32 No. 7088

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 290 NOVEMBER, 1932

The Story of Field A of the Massachusetts Agricultural Experiment Station

A Review of Experiments With Nitrogen Fertilizers

By Fred W. Morse

The year 1932 marks the fiftieth anniversary of the formal organization of agricultural research at Massachusetts State College. It was in November of 1882 that the Experiment Station was established, and field plot experiments begun the next year represent some of the first activities. It seems fitting, therefore, after this fifty-year period, that results from this work be compiled and recorded in permanent form. This bulletin represents such an effort.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE STORY OF FIELD A OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

A REVIEW OF EXPERIMENTS WITH NITROGEN FERTILIZERS

By Fred W. Morse, Research Professor of Chemistry

Field A is the field first to be devoted to fertilizer experiments at the Massachusetts Agricultural Experiment Station. The experiments have been described with more or less detail in the annual reports of the Station. It is now attempted to bring together the disconnected reports and summarize the results in a relatively brief article as a background for future work on these plots.

A clear description of the field is given in excerpts from the report by Professor Manly Miles in the First Annual Report of the State Agricultural Experiment Station in 1883.

THE FIELD PLATS

After a careful examination of the area assigned for field experiments and a detailed study of its previous history as to cropping, with reference to its present agricultural condition—in which I was materially aided by the advice and suggestions that were kindly given by Hon. Levi Stockbridge, ex-president of the Agricultural College—two series of plats were selected that presented the required conditions of uniformity and surface soil and exposure.

When the trenches for laying the tiles had been dug, it was likewise found that the subsoil in each series of plats was quite as uniform in its characteristics as the surface soil. . . . .

The plats are two rods wide and eight rods long, giving an area of one-tenth of an acre each. . . .

The east tier of plats (with odd numbers[1]) have been under ordinary field culture, and for several years past in grass, which is badly "run out," the hay having been removed without the return of an equivalent in the form of manure; so that their present condition, as represented by their past history, is well adapted to the proposed permanent experiments. . . . .

A main drain of round tiles laid four feet deep has been made along the east side . . . . (four feet from the line of plats), with wells of sewer pipe opposite the middle of each plat, for the purpose of collecting samples of the drainage waters from the lateral drains which open into them. . . .

The laterals, of two-inch round tiles, are laid through the middle of each plat, and have their outlet in the wells twelve inches above the grade of the main drain. . . . .

The work of digging trenches for the tile drains was begun April 16th, and the laterals on the east tier of plats were completed May 10th. . . . .

EXPERIMENTS WITH INDIAN CORN

In accordance with the plan of experiments, . . . corn was grown on the east series of plats . . . , without manure, and under the same conditions as to management, for the purpose of testing the relative fertility of the plats. . . . The plats, of one-tenth of an acre each, are two rods wide and eight rods long, and they are separated by a space four feet wide, on which no crop is grown.

The soil is a friable loam, with a retentive subsoil of clay that is nearly filled with gravel and small stones in the lower strata.[2]

There is a remarkable uniformity in the soil and subsoil of the different plats, both as to apparent fertility and physical condition, with the exception of plat 0, where a large manure pile had formerly been made. . . . .

In all operations of ploughing, cultivating, planting, hoeing and harvesting, the work was done lengthwise of the field, and consequently across the plats, so that each plat received the same treatment, as far as possible. . . . .

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[1] Later renumbered 1 to 10 and designated Field A.

[2] The Bureau of Soils classified this soil as Norfolk sandy loam but changed it later to Merrimac. "Soils of the United States." U. S. Dept. Agr., Bur. Soils, Bul. 55, p. 158.

"Longfellow corn" was planted June 2, in hills, forty-four inches apart each way . . . . As the first and second days of June were the first really warm days of the season, the late planting did not at the time seem to be a serious disadvantage. . . . .

The plats were quite free from weeds on the start, and the repeated cultivation and hoeing left the crop perfectly clean in its subsequent growth.

On the night of September 3 a hard frost severely injured the corn . . . . as we were dependent on the farm for labor, we were obliged to wait until the 7th inst., when the crop was cut close to the ground and put in stooks to cure. . . . . The corn was husked October 18 . . . . The corn and stalks were hauled to the barn and separately weighed. . . . .

It should be noted that from an error in marking and planting, made by the unskilled hands assigned me, it became necessary to transplant several rows of corn on plats 13, 15 and 17,[3] . . . . the transplanted hills were checked in their growth and never fully matured. This will, in part at least, account for the lower yield of both corn and stalks on these plats.

Professor Miles was not connected with the experiments after the first year. The arrangement of the plots and the drains has been unchanged and the method of cultivation across the plots has been maintained. Until 1896, the experiments were directed and reported by Dr. Charles A. Goessmann, the first director of the Experiment Station. In 1884 he reported:

During the past season the field has been planted again with corn, for corn fodder, without the application of manure of any description. . . . . the corn (variety: Clark) was planted in drills, two and one-half feet apart, at the rate of two bushels per acre, on the 24th of May . . . . The plants started well in the spring, yet began soon to fall behind, in general appearance, other fodder cornfields in the vicinity, upon fertilized lands.

At the beginning of blooming it turned gradually yellow, failed to produce grain-bearing cobs, ...

The corn was cut on the first of September and stacked in the field for drying. The entire yield of corn fodder from this piece of land, one and one-tenth of an acre in size, amounted to 5,040 pounds, with a moisture of thirty per cent.

The soil is evidently in suitable condition for studying the special effects of various forms and kinds of plant food . . . .

SOIL AND FERTILIZER TEST WITH CORN

Corn was the crop grown for the next five years upon these plots. A variety of flint corn known as Clark was used each year, and the seed was planted in hills 12 to 14 inches apart in rows 3 feet and 3 inches apart. The time of planting was in the latter part of May each year, and the crop was cut in the earlier part of September. Under the conditions of the experiment, until the season of 1889, the corn did not mature ears sufficiently to be husked and was consequently weighed from each of the plots as fodder, after being cured in shocks until October.

The use of fertilizers was begun in 1885. The amount of each fertilizer and its allocation to the different plots was varied somewhat each year until 1889. The arrangement of plots and their fertilizers is shown by a chart and the yields of corn are given in Table 1.

The table includes the yields for 1883 but omits those of 1884 because in that year the crop from the field was weighed as a whole and then divided equally among the plots. The amount, 458 pounds per plot, was less than any yield of the previous year.

Only one kind of fertilizer was used upon any plot in 1885, and Plot 0 of the previous years was omitted from the records until 1889.

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[3] In Table 1, these plats are numbered 7, 8, and 9.

FERTILIZER PLAN WITH CORN
1885-1888

Plot	1885	1886	1887	1888
1	25 lbs. sodium nitrate.	50 lbs. sodium nitrate.	50 lbs. sodium nitrate. 50 lbs. muriate of potash.	50 lbs. muriate of potash.
2	Nothing.	Nothing.	Nothing.	50 lbs. sodium nitrate.
3	30 lbs. dried blood.	60 lbs. dried blood.	60 lbs. dried blood. 100 lbs. dissolved boneblack.	100 lbs. dissolved boneblack.
4	Nothing.	Nothing.	Nothing.	Nothing.
5	25 lbs. ammonium sulfate.	50 lbs. ammonium sulfate.	50 lbs. ammonium sulfate. 97 lbs. sulfate of potash-magnesia.	97 lbs. sulfate of potash-magnesia.
6	Fallow.	Fallow.	Fallow.	Nothing.
7	50 lbs. dissolved boneblack.	100 lbs. dissolved boneblack.	100 lbs. dissolved boneblack. 50 lbs. muriate of potash.	50 lbs. muriate of potash.
8	Nothing.	Nothing.	Nothing.	50 lbs. ammonium sulfate.
9	25 lbs. muriate of potash.	50 lbs. muriate of potash.	50 lbs. muriate of potash.	50 lbs. muriate of potash.
10	48.5 lbs. sulfate of potash-magnesia.	97 lbs. sulfate of potash-magnesia.	97 lbs. sulfate of potash-magnesia. 60 lbs. dried blood.	97 lbs. sulfate of potash-magnesia. 100 lbs. dissolved boneblack.

In his report for 1885, Director Goessmann states:

. . . . we notice that the application of potash compounds alone, ... has had a marked effect on the quantity . . . . of the corn fodder raised, ...

. . . . it seems justifiable to conclude that a deficiency of the soil in available potassa controlled more than that of any other essential article of plant food the final yield of the crop.

In 1886, without changing the kinds of fertilizers, the quantities used were doubled. There was no change in the order of crop yields, however.

In 1887, the fertilizers on some of the plots were added in pairs. The addition of potash to nitrogen on Plots 1 and 5, and to phosphoric acid on Plot 7, doubled the yields which had been obtained with those elements alone. Phosphoric acid

TABLE 1—YIELD OF CORN

(Pounds per plot.)

Plot	1883		1885	1886	1887	1888	1889	
	Ears	Stover	Fodder	Fodder	Fodder	Fodder	Ears	Stover
0	326	578	.....	.....	.....	.....	158	342
1	233	445	N 480	N 430	NK 720	K 617	172	476
2	227	410	310	250	165	N 303	201	376
3	241	437	N 350	N 310	NP 240	P 150	192	426
4	221	400	300	250	130	114	97	284
5	217	383	N 360	N 280	NK 635	K 564	129	359
6	219	390	Fallow	Fallow	Fallow	193	175	367
7	197	356	P 280	P 255	PK 730	K 676	41	484
8	174	340	250	195	165	N 191	121	238
9	191	355	K 945	K 840	K 655	K 553	58	417
10	219	400	K 845	K 895	NK 940	PK 737	172	467

N—Nitrogen. P—Phosphoric acid. K—Potash.

1883. Grass-land plowed and planted without fertilizer of any kind.

1889. All plots fertilized with phosphoric acid and potash.
Plots 1, 2, 3, 5, 6, 8, and 10 received nitrogen; Plots 4, 7, and 9 did not receive it.
Plot 0 received farm manure.

added to nitrogen on Plot 3 did not improve the yield in the least. Nitrogen added to potash on Plot 10 increased the yield a little when compared with the previous year.

In his report for 1887, Dr. Goessmann said:

> The beneficial influence of a potash supply on the yield of fodder, upon our experimental plats, is in every instance unmistakable.

The continuation of the experiment in a similar manner in 1888 brought about a change. The continuous use of potash alone brought about a marked deterioration in yield on Plot 9. Nitrogen was withheld on Plots 1 and 5, with the result that potash alone did not maintain the yields obtained on these plots the previous year. The withholding of phosphoric acid on Plot 7 produced a similar result.

Dr. Goessmann's report in 1888 contained the following statement:

> A manuring for three successive years with potash alone has sufficed in our case to terminate its beneficial effect on the natural productiveness of the soil, as far as the corn crop is concerned. More complete manures are required to restore a desirable degree of fertility of the soil.

The application of nitrogen to Plots 2 and 8 resulted in a positive increase over the preceding year; while the substitution of phosphoric acid for nitrogen on Plot 10 did not maintain the yield of the previous year.

The fertilizer plan was changed in 1889 with the object of studying the influence of different kinds of nitrogen compounds as fertilizers when the soil was supplied with ample quantities of available phosphoric acid and potash in standard materials.

Corn was again the crop and was handled as in the preceding years. Three of the plots, (4, 7, and 9) did not receive any nitrogen and had not received any

since the field was first plowed in 1883. All the other plots received equal amounts of nitrogen, but in different kinds of fertilizers. Plot 0 was again included. For this year it is sufficient explanation to mention that all the plots received fertilizers supplying phosphoric acid and potash in amounts like those of 1885, while all but three received nitrogen as in that year.

We have then a crop of corn liberally fertilized which can be compared with the first crop on unmanured soil. It will be noted that not one of the plots equals the first year, with the exception of 10, which in total crop barely exceeds its first year. In all cases the yields of ears are lower in this fertilized crop. The crop of 1883 was grown upon new land, even though it was "run out" as a producer of hay. The turf underlying that corn evidently contained a reservoir of fertility fully equal to that added in the fertilizers of 1889. The poor yields on Plots 4, 7, and 9 are especially striking and will be recalled later in this article.

In the report for 1889, there is the statement that the larger part of the late summer was cold and wet and for this reason unfavorable for raising fodder corn. A difference in average temperature between the two seasons would affect the development of the corn crop in a way that could not be wholly overcome by fertilizers. The first crop was frost-bitten early in September, which would cause a quickened drying of the leaves and possible losses by breakage of them in handling. Hence we have in each season under comparison a weather condition which cannot be evaluated in weight of crop.

During the recorded history of this field there have occurred variables which have affected the field unevenly for a time. The most common variables were weather conditions such as a drenching rain at a critical stage, an unseasonable frost, a severe drought, or a hard winter. Theoretically, all parts of a field are equally exposed to the weather. Actually, variations in soil or fertilizers are much exaggerated by an extreme change in weather. Sometimes the variable was due to the lack of facilities encountered in pioneer work as in these early experiments.

It is now well known that it is difficult to find a field of an acre or more that is truly uniform in soil and subsoil throughout its area. This experimental field, like the experiment station itself, has developed under changing conditions which could not be foreseen and to which adjustments were necessary.

COMPARISON OF NITROGEN FERTILIZERS

Beginning in 1889 and continuing with but little change until 1919, a fertilizer experiment was planned with the object of comparing three distinct kinds of nitrogen fertilizers represented by the standard chemicals of that period, viz., sodium nitrate, ammonium sulfate, and dried blood. The other essential elements of soil fertility, phosphoric acid and potash, were supplied to all plots alike in standard chemicals of the times. Phosphoric acid was contained in dissolved boneblack. Potash was applied in two distinctly different compounds, muriate of potash and sulfate of potash-magnesia. In the long run this comparison of two potash compounds showed them to be equally effective and cannot be said to have influenced the comparison of the nitrogen fertilizers.

The quantities of chemicals for the different plots are given in the following chart. In terms of pounds per acre they would contain 45 pounds nitrogen, 80 pounds available phosphoric acid, and 125 pounds potash. In 1894 and 1895 the quantities of phosphoric acid and potash were doubled but with no appreciable

effect. In 1917, because of war conditions, the quantity of potash was reduced 40 per cent to 75 pounds per acre and the reduction was maintained until the close of this study.

Fertilizer Plan for Thirty Years
1889-1918

Plot 0.—800 lbs. manure, 32 lbs. sulfate of potash-magnesia, 18 lbs. dissolved boneblack.

Plot 1.—29 lbs. sodium nitrate, 25 lbs. muriate of potash, 50 lbs. dissolved boneblack.

Plot 2.—29 lbs. sodium nitrate, 48.5 lbs. sulfate of potash-magnesia, 50 lbs. dissolved boneblack.

Plot 3.—43 lbs. dried blood, 25 lbs. muriate of potash, 50 lbs. dissolved boneblack.

Plot 4.—No nitrogen, 48.5 lbs. sulfate of potash-magnesia, 50 lbs. dissolved boneblack.

Plot 5.—22.5 lbs. ammonium sulfate, 48.5 lbs. sulfate of potash-magnesia, 50 lbs. dissolved boneblack.

Plot 6.—22.5 lbs. ammonium sulfate, 25 lbs. muriate of potash, 50 lbs. dissolved boneblack.

Plot 7.—No nitrogen, 25 lbs. muriate of potash, 50 lbs. dissolved boneblack.

Plot 8.—22.5 lbs. ammonium sulfate, 25 lbs. muriate of potash, 50 lbs. dissolved boneblack.

Plot 9.—No nitrogen, 25 lbs. muriate of potash, 50 lbs. dissolved boneblack.

Plot 10.—43 lbs. dried blood, 48.5 lbs. sulfate of potash-magnesia, 50 lbs. dissolved boneblack.

The arrangement of plots for the comparison of the fertilizers was influenced by the treatment they had received in the previous period, and at the outset the different plots were not as nearly uniform in their fertility as they apparently were in 1883.

Plot 0 had been omitted from the experiment after 1884 because it showed the residual effects of a manure pile which had been upon its surface at some previous period. During this omission from the records it had probably been planted with corn without fertilizer. It was restored to the experiment in 1889 and was fertilized with stable manure supplemented by boneblack and sulfates of potash and magnesia. The amount of manure, 800 pounds, was calculated from the average composition determined by numerous analyses and contained an amount of nitrogen equal to that in the chemical fertilizers used. The supplementary phosphoric acid and potash were necessary to equalize Plot 0 with the other plots. This plot was the only representation of this treatment and must stand on one annual result.

Plots 1 and 2 were selected for nitrate of soda because they had each received that fertilizer at one time or another in the previous years. They adjoined and were frequently fairly close together in yields. In 13 years out of 33, their individual yields were within 1 per cent or less of their average. Plot 1 definitely excelled Plot 2 in 14 harvests, while the latter excelled in 6.

Plot 3, which received dried blood in the new plan, had also been dressed repeatedly with it alone in the previous years. It was paired with Plot 10 at the other end of the field. In the subsequent years, Plot 10 excelled Plot 3 in 15 harvests, while it was excelled by the latter 13 times. In five seasons, their yields were so nearly alike that they may be considered as equal.

Plots 4, 7, and 9 were selected as check plots because they had not received any nitrogen during the preceding years. Otherwise they had not been treated alike and had yielded different weights of crops. Their records have been carefully compared to ascertain whether there were consistent differences in their native fertility; but none could be discovered. Sometimes one plot has been the best of the three and at others it has been the poorest. Plot 7 has been the highest producer 12 times and the lowest 8 times; while Plot 4 has been highest 14 times and lowest 15 times; and Plot 9 highest 7 and lowest 10 times. Plot 9 may perhaps be considered nearest the average as a producer.

On the whole, the choice of Field A as a reasonably uniform field has been borne out by the successive harvests.

The three plots which were chosen for the applications of ammonium sulfate had an uneven start insofar as their records for the early years bear witness. Plots 5 and 8 had each received ammonium sulfate, but otherwise had been treated quite unlike and had borne unequal harvests. Plot 6 had been treated unlike any of the others for three years and this will be shown by Director Goessmann's report for 1888.

. . . . during the years 1885, 1886 and 1887, the plat was ploughed, harrowed and treated with the cultivator in the same manner and at the same time as the remaining plats. During that entire period no manurial matter of any description was applied. The appearance of every description of vegetation was, as far as practicable, prevented by a timely use of the cultivator.

At the beginning of the past season, after having produced no crop for three succeeding years, it was prepared in the same way and at the same time as the other plats. . . . . No manurial matter was on that occasion applied to plat 6. The date of planting the corn, and the subsequent treatment of the crop to the time of harvesting, was the same in all cases. The yield of fodder corn upon plat 6 was the third lowest in the scale including all plats; . . . . It was also the poorest-looking crop upon field "A" during the larger portion of the season . . . . Our observation in this connection confirms the results of more recent careful investigations into older systems of agricultural practice. Black fallow, as a rule, does not materially benefit the productiveness of an exhausted soil, ...

These three plots had one thing in common in 1889, the first year of the new series. They had deteriorated markedly from their yields in 1883.

Plots 5 and 6 adjoined like Plots 1 and 2 and each had a check plot without nitrogen beside it. Plot 8 was separated from the other two by a check plot and had a check plot on the other side also. For years the individual yields of these plots were erratic. Sometimes one of the plots would yield less than the plot without nitrogen, which was beside it. Ultimately, the problem was solved. Bulletin 204 of this experiment station is devoted to these three plots in comparison with those without nitrogen, but the data will be included in this study.

Interest in fertilizers is centered primarily in their effects on plants, the measure of which is the yield by weight or volume of the portions of plants that have economic importance. The clearest presentation of a mass of data accumulated over a long term of years from a variety of crops is accomplished by grouping together the annual yields of one kind of crop and comparing the relative effects of the different fertilizers season by season.

Oats

Oats constitute the first group of crops because oats in 1890 were the first crop to follow the corn crop of 1889. Winter rye followed in 1891. Then in 1892 began a rotation in which soy beans alternated with oats for several years

with the object of building up the plots that did not receive nitrogen in fertilizer, because it had become definitely established that leguminous plants, of which the soy bean was one type, were able to use nitrogen from the air for their growth and their stubble and roots would thereby enrich the soil with the nitrogen contained in them. Consequently, the oat crops of 1893, 1895, and 1897 followed soy beans, the roots and stubble of which were left in the soil.

The effect of the first soy bean crop appeared beneficial, especially in the production of oat straw which was double the quantity produced in 1890. Nitrogen is regarded as a promoter of vegetation rather than fruit. The Plots 4, 7, and 9 were especially improved in both straw and grain.

The crop of 1895 showed no gains over 1893 in production of straw, except on Plot 8. This plot had received a dressing of 200 pounds of air-slaked lime the year before, which stimulated a larger yield of soy beans and apparently increased vegetation in the oats of this year. The yield of grain was larger than in 1893 on 8 of the plots, which included all the different kinds of fertilizer.

In 1897, the production of straw decreased on all but the nitrate plots, 1 and 2, and the yields of grain were less on all but Plot 8. Plots 4, 7, and 9 had shrunk in both grain and straw to a lower point than in 1890. The rotation with soy beans had not resulted in any permanent improvement in soil fertility.

Before sowing the oats in 1898, the entire field was limed with approximately 2000 pounds per acre of freshly slaked lime. The yields on all plots were much lower than in 1897 and excepting Plot 8 even less than in 1890. This is similar to the result of repeated crops of corn ending in 1889.

TABLE 2—YIELD OF OATS

(Pounds per plot.)

Plot	Form of nitrogen	1890		1893		1895		1897		1898*	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
0	Manure	120	195	131	399	134	254	125	220	83	125
1	Nitrate	128	234	135	555	160	330	159	500	103	150
2	Nitrate	129	236	146	454	150	330	147	400	115	175
3	Organic	116	229	166	534	149	331	122	215	96	155
4	None	90	170	160	430	110	233	69	120	56	80
5	Ammonia	111	219	79	551	190	360	137	340	103	135
6	Ammonia	124	261	102	498	155	405	97	275	109	160
7	None	110	210	119	431	136	292	77	120	72	95
8	Ammonia	59	161	95	325	92	458	127	350	123	155
9	None	101	189	110	370	123	217	75	130	76	95
10	Organic	140	255	125	485	169	381	126	220	112	135

*Lime applied.

The comparative efficiency of the four different kinds of nitrogen fertilizers is not readily determined in these successive oat crops. There is but one manure plot against two plots with nitrate, two with blood and three with ammonia. Manure must necessarily stand by its one annual crop. The two nitrate crops may be averaged and also the two blood crops. It is problematical how to compare the ammonia crops fairly with the others. It has been thoroughly demonstrated that ammonium sulfate should have the benefit of the presence of calcium

carbonate in the soil in order to be most productive as a nitrogen fertilizer. The other kinds may or may not be more efficient in the presence of lime. During the years of this comparison of nitrogen fertilizers, ammonium sulfate did not uniformly have the conditions for good results. In some seasons, the material seemed to have been positively injurious. Therefore, for the purpose of this review the best two yields in each year are averaged for comparison with nitrate and blood.

The crops of oats in this group consisted of two distinct parts, grain and straw. The total of the two weights will be used as the standard for rating the different fertilizers, because nitrogen is especially effective in promoting growth. In this group of crops there were but two instances where grain and straw had to be combined for comparison. Ammonium sulfate was foremost in productiveness in 1890, 1895, and 1898. Sodium nitrate led in 1897 and blood was ahead in 1893. Manure was least effective. The ratio of grain to straw varied from year to year, being widest in 1893, the maximum year of both grain and straw, and narrowest in the year of least production, 1898. While variety of seed oats was changed from year to year, the trend of grain to straw indicated that a generous development of stem and leaf was necessary for a big crop of grain. There was no constant difference in ratios that could be attributed to any one nitrogen fertilizer, but the check plots without nitrogen had narrower ratios of grain to straw than any of the plots with nitrogen, which accords with the trend of the years.

Soy Beans

The next group of crops is soy beans, and consists of two subgroups. The crops of 1892, 1894, and 1896 were alternated with the oats previously discussed. A different variety was planted each year and the crop was cut for the silo and weighed green. The first crop was a late variety and did not reach the blossom stage. The second crop was an early variety and bore pods at harvest time. The third crop was a medium season type and was well filled with pods but was a much larger type of plant than the early one of 1894.

The most striking yields in these three crops are those without nitrogen. Soy beans were not apparently accomplishing much at obtaining nitrogen from the air. This was possibly due to the lack of the specific bacteria in the soil at this period, since soy beans had been introduced only a few years before.

The behavior of Plot 8 illustrates the benefit of lime as an accompaniment with ammonium sulfate. No better than plots without nitrogen in 1892, it responded to the liming of 1894, which carried it to the highest standing of all in 1896. Why Plot 8 was most frequently the least productive of the three plots treated with ammonium sulfate has never been solved.

Plot 10, supplied with nitrogen in dried blood, was apparently no better than the plots without nitrogen in 1892. In the report for that year, the suggestion was made that this might have been due to a scanty seeding, as it was the first plot to be sown with the seed drill.

The crops of 1901 and 1903 were preceded and followed by potatoes. The soy beans were matured and separated into seed and straw. Soy beans continued to respond to nitrogen fertilizers although by now the soil had become well inoculated with their specific bacteria. Dr. Brooks states in his report for 1901:

> The development of nodules upon the roots of the crop this year was very abundant. In spite of this fact, . . . the crop on the no-nitrogen plots stands considerably below that on the other plots.

The inferiority of the crop of 1903 was due to the season, which was reported to be "highly unfavorable to the growth of the crop, which is one requiring protracted warm weather."

The relative effectiveness of the different nitrogen fertilizers is again difficult to measure. In the first year, 1892, the nitrate plots stood out as superior; but after Plot 8 was limed in 1894, the two best ammonia plots exceeded the nitrate plots both in that year and in 1896. In the matured crops of 1901 and 1903, the manure plot was slightly superior to the average of any other pair of plots. The ammonia plots in 1903 appeared to have lost the benefit of the liming, which all plots received five years earlier in 1898.

Brooks mentioned an interesting observation about the nitrate plots in his report for 1903:

> It has been repeatedly noticed that where nitrate of soda is the source of nitrogen, the leaves, especially in the early stages of growth, assume a crinkled or wrinkled appearance, and fail to reach full size and normal development. . . . . As the season advances, the soy bean plants as a rule show a more normal leaf development; and, although the crinkling this season was excessive, the yield on the nitrate of soda plots does not appear to have been materially decreased, as a consequence.

The ratio of seed to straw was nearly constant for the crops on manure, nitrate, and organic nitrogen plots, 1 : 1.41-1.45. Ammonia gave a wider ratio, 1.61 and 1.57, while without nitrogen the ratio varied from 1.50 to 1.67.

Soy beans, although a legume, were always benefited by nitrogen fertilizers; but no one of them was consistently most efficient.

TABLE 3—YIELD OF SOY BEANS

(Pounds per plot.)

Plot	Form of nitrogen	1892	1894	1896	1901		1903	
		Green	Green	Green	Seed	Straw	Seed	Straw
0	Manure	2210	600	1760	190	270	138	201
1	Nitrate	2290	625	1850	182	275	119	170
2	Nitrate	2290	700	1840	189	250	144	208
3	Organic	2090	525	1510	166	260	96	201
4	None	1440	405	1130	167	260	99	170
5	Ammonia	1935	645	1582	162	230	97	148
6	Ammonia	1970	615	1870	179	305	68	116
7	None	1430	480	1240	149	235	64	112
8	Ammonia	1450	680*	1980	167	255	86	139
9	None	1460	470	1060	162	220	51	75
10	Organic	1490	570	1530	192	260	126	122

*Lime applied.

Potatoes

Since potatoes were associated with the soy bean crops, their group will be discussed next.

The crop of 1900 followed a crop of mixed clover and grass, and consequently had a sod turned under as a preparation for it. The next two crops had only soy

bean stubble as residual organic matter. The fourth crop, in 1917, followed a heavy crop of Japanese millet which leaves a thick stubble and root mass, but presumably not as rich in nitrogen as the clover sod.

The crop of 1900 shows the value of a clover sod as a store of nitrogen. The plots without nitrogen, 4, 7, and 9, equal several of the plots which received those fertilizers, although the average yield is slightly lower than the other averages. The manure plot exceeds any of the averages.

The crop of 1902 was produced from two distinct varieties of seed; Plots 0, 1, 2, and part of 3 received a wholly different variety of seed from that used for the other plots. This may have caused the lower yields on these plots when compared with the rest of the field. Manure was noticeably superior to nitrate. Organic nitrogen was superior to ammonia, which at best was little better than no nitrogen.

In 1904, the manure plot again excelled all other plots. Ammonia again was little if any better than no nitrogen. Soy bean stubble is not equal to a clover sod as a supply of nitrogen for a following crop. Ammonium sulfate showed lack of accompanying lime. Plot 10 needs the following note, made in the report for 1904:

> . . . . the potatoes on this plot were covered by hand, while those on the other plots were covered by the use of the plow. The potatoes on this plot came up much more quickly and more vigorously than those on the others, and showed decided superiority in growth from the start.

The crop of 1917 was much superior to the crops of the earlier years, which may have been due to the abundant residual organic matter from the millet stubble. Brooks mentioned the value of organic matter in the soil for potatoes in his report on the crop of 1904, as follows:

> Experiments in continuous potato culture . . . . have shown in a striking manner the dependence of this crop upon the presence of a suitable proportion of organic matter in the soil.

Nitrate plots were definitely superior to the others, and organic nitrogen was not far behind.

These important results stand out with the potato crops here grouped: Nitrogen fertilizers were of comparatively little value following a clover sod; manure was superior to chemicals when the soil lacked organic matter; soy bean stubble was ineffective as a source of nitrogen.

TABLE 4—YIELD OF POTATOES

(Pounds per plot.)

Plot	Form of nitrogen	1900	1902	1904	1917
0	Manure	1399	1007	1669	1865
1	Nitrate	1198	861	1356	1899
2	Nitrate	1455	867	1326	2214
3	Organic	1153	1127	1062	1977
4	None	1387	1011	756	1890
5	Ammonia	1343	1002	1056	1599
6	Ammonia	1247	1218	696	1668
7	None	1268	1114	690	1458
8	Ammonia	1215	978	876	1644
9	None	1108	1013	1062	1464
10	Organic	1519	1369	1536	1914

Hay

Several crops of hay were produced in these experiments, but not in systematic rotation with other crops. Numerous efforts to secure a crop of clover are mentioned in the records of the field but repeatedly the stand was so reduced by winterkilling that the remaining plants were plowed under in the spring and an annual crop was substituted. The first hay crop reported was in 1899. Red clover had been sown after a crop of oats late in the previous August. The field had been limed before the oats were sown and the catch of clover was successful. The winter of 1898-99, however, injured it somewhat; April and May were unusually dry and the first crop was small. The season was favorable for the second cutting, which was made August 21. Considerable grass had appeared in all plots. Both crops are combined in the table.

Although limed the previous year, the ammonia plots were inferior to the other nitrogen plots. Manure produced the best crop.

The years 1907, 1908, 1909, and 1910 were devoted to attempts to grow clover. The field had been limed at the rate of one ton per acre in 1905. Peas and oats in that year and corn in 1906 had been the preceding crops. Alsike clover was sown in the corn. In April, 1907, additional alsike clover seed was sown. Two cuttings were made, July 17 and October 7, the second of which was small. The field was carried over to the next season, when in May, 1908, the records state that grasses were replacing clover and at the time of cutting, July 1, the plots contained mostly timothy and very little clover.

After the hay was removed, the field was plowed and harrowed. Alsike clover was sown on August 20. Late in November, there was a fairly uniform but thin stand of clover.

The crop of 1909 consisted principally of alsike clover, except on Plots 5, 6, and 8, where by actual weights the crops were half weeds, mainly sorrel. The field was plowed after the removal of the hay and on August 7 alsike clover was again sown. Previous to the seeding, an application of agricultural lime had been made to the east half of the field at the rate of 2500 pounds per acre.

In April, 1910, all plots had a good stand, but there was considerable grass mixed with the clover. As the season advanced timothy overtopped the clover. The hay was harvested on July 9.

These four seasons were notable for severe droughts during the growing season and a scanty rainfall for each year. The nitrate plots bore the heaviest crops in 1907; organic nitrogen gave a little the best yields in 1908; the two kinds were about equal in 1909; and in 1910, the ammonia plots responded to lime by practically equaling the other nitrogen plots in yields.

The crop of 1915 was seeded in the spring of 1914 with oats as a nurse crop. A mixture of timothy, red top, and red clover was used. After the removal of the oats, the clover predominated over the grasses, especially on the limed halves of the plots. The crop was not cut in the fall but permitted to remain as a protection to the roots. In the spring of 1915, the plots had passed the winter in excellent condition. Clover predominated except on the unlimed halves of ammonia Plots 5, 6, and 8, where red top constituted about half the crop.

The first cutting was made June 18, and the second on August 20. The season had been unusually dry in May, normal in June, and abundantly moist in July and August. Organic nitrogen and ammonia plots averaged nearly alike in productiveness and exceeded the average of the two nitrate plots.

TABLE 5—YIELD OF HAY

(Pounds per plot.)

Plot	Form of nitrogen	1899	1907	1908	1909*	1910	1915	1920	1921
0	Manure	508	375	430	415	695	805	351	500
1	Nitrate	443	445	630	565	767	850	542	524
2	Nitrate	422	450	570	440	700	775	538	534
3	Organic	345	355	590	415	660	830	449	535
4	None	336	405	340	395	640	845	343	590
5	Ammonia	342	325	358	437	722	770	539	468
6	Ammonia	375	272	215	420	700	835	457	431
7	None	343	385	463	315	675	783	305	561
8	Ammonia	407	300	505	450	680	820	670	590
9	None	421	325	465	375	705	700	296	524
10	Organic	456	504	635	590	715	835	582	505

*Lime applied.

The two successive crops of 1920 and 1921 represent a new arrangement of fertilizers and lime, described fully in connection with the corn crops. It is sufficient here to state that in 1919 the application of lime was made at the rate of 2000 pounds ground limestone per acre on the north half of each plot, except 6 which was left unlimed, and 8 which was limed throughout. Also the organic nitrogen fertilizers were changed at that time to cyanamid on Plot 3 and dry ground fish on Plot 10, because dried blood was no longer a common fertilizer but was in great demand as food for animals.

The crop of 1920 was seeded in the corn the summer before, and the crop of 1921 was the second from the same seeding. The crop consisted of mixed timothy, red top, and clover. Clover was the least of the three in proportion. Red top prevailed on the unlimed areas. The fertilizers had been applied as a spring top-dressing in each year.

There are two striking results in these two crops. The limed ammonia plots 5 and 8 are much superior to the other nitrogen plots in 1920 and equal to the best in 1921. Plots without nitrogen in 1921 excel all those with nitrogen and are much heavier than in 1920.

Corn

The corn crops were produced under varying soil conditions. That of 1906 followed oats and peas of the year before, but an attempt was made to seed the field with clover, after plowing under the stubble of the oats and peas. The clover was so much winterkilled that it, too, was plowed under in the spring of 1906, and corn was planted. The largest proportion of clover was on Plot 0 and the least on Plots 5 and 6. The manure plot is best this year, which may be due in part to the clover that was on this plot when plowed.

In 1911, the corn was grown upon a clover and timothy sod from the previous hay crop. In this year, the maximum yield was on the plots without nitrogen, and the ammonia plots were second. The crops of 1912, 1918, and 1919 followed tilled crops of the previous year. Plots without nitrogen were noticeably inferior. Nitrate plots and organic plots shared first and second places between them, alternating in standing with the years.

Some minor changes were made in the applications of fertilizers and lime in 1919. Up to this time, dissolved boneblack had been used continuously as the phosphoric acid fertilizer and dried blood as the organic nitrogen fertilizer. Both were no longer in common use. Acid phosphate, or plain superphosphate as dissolved rock phosphate was called, was now the standard source of phosphoric acid and was substituted for the boneblack. Dried blood was now in demand as a food for calves and pigs. A new synthetic nitrogen fertilizer, cyanamid, was introduced on Plot 3; and a standard organic substance, ground fish, was substituted on Plot 10. The application of fish carried with the nitrogen a small addition of phosphoric acid, which was ignored because there had always appeared to be a surplus of that plant food and the phosphoric acid in fish was less soluble than that yielded by superphosphate.

Lime had been liberally applied on the east half of every plot, and with most crops there was a sharp demarcation between the unlimed and limed areas. But a comparison of yield between the two halves was unfair because the east side of the field was definitely, though slightly, moister than the west half. In 1919, one ton per acre of ground limestone was applied to the north half of each plot except Plot 6 and Plot 8. These were duplicate plots with ammonium sulfate and it was deemed to be a better comparison of the value of lime as an accompaniment to ammonium sulfate with Plot 8 limed throughout and Plot 6 left without any addition.

The change in sources of phosphoric acid and organic nitrogen did not appear to alter the relative standing of the different fertilizers.

The proportions of weights of ears to weights of stover in the different corn crops indicate that the addition of nitrogen promoted the development of ears.

In 1883, the first year of these experiments, Longfellow flint corn was grown without fertilizer; the yields were fairly uniform on all the plots and the ratio of ears to stover averaged 1 : 1.8.

In 1889, the first year of the comparison of nitrogen fertilizers, Plots 7 and 9 without nitrogen bore small quantities of ears, while the weights of stover were equal to those on the nitrogen plots. The proportions of ears to stover on 7 and 9 were respectively 1 : 12 and 1 : 7, while the crops on the nitrogen plots had an average ratio of 1 : 2.3. Plot 4, also without nitrogen, differed somewhat from Plots 7 and 9. Its crop was somewhat heavier in weight of ears, but much less in stover, and the ratio was 1 : 3.

Plot 4 had been without fertilizer of any kind until 1889, while Plot 7 had received phosphoric acid and potash, and Plot 9 had received potash. Plot 4 had borne about one-third as much fodder as had been produced on 7 and 9, due to the lack of available potash. In 1889, the latter plots had exhausted their soil nitrogen more than Plot 4, while accumulating available potash. The failure to produce ears when nitrogen is lacking was noticeable. The need of potash to produce growth was also apparent.

Subsequent corn crops corroborated the relation of nitrogen to ear production. Rustler dent corn was grown in 1906, 1911, and 1912. The crop of 1911 was grown upon a clover sod, which supplied all the nitrogen that the different plots needed, and the proportions of ears to stover were nearly uniform around 1 : 0.9. The following year, 1912, the ratios separated a little and averaged 1 : 0.85 with the nitrogen plots and 1 : 1.05 for the plots without nitrogen. The crop of 1906 had wider differences between the two groups of plots, with an average ratio 1 : 1.1 for the nitrogen plots and 1 : 1.7 for the other group.

Longfellow flint corn was planted in 1918 and 1919. In the former year, ratios of ears to stover were transposed. The average for the nitrogen plots was 1 : 1.6 and for the plots without nitrogen the ratio was 1 : 1.4. Plots 7 and 9 in 1919 returned to the usual form. The average ratio of all nitrogen plots was 1 : 1, while the ratio was 1 : 1.2 for those two plots. Plot 4 was quite out of line, with a larger weight of ears than of stover. The weather conditions in 1918 were unusually hot and dry in July and August with the latter month slightly hotter than the former. Lack of water lessened growth on plots without nitrogen and produced an abnormal proportion of ears and stover.

TABLE 6—YIELD OF CORN

(Pounds per plot.)

Plot	Form of nitrogen	1906		1911		1912		1918		1919	
		Ears	Stover	Ears	Stover	Ears	Stover	Ears	Stover	Ears	Stover
0	Manure	721	650	497	475	650	500	454	685	473	430
1	Nitrate	525	630	590	485	690	640	479	905	530	615
2	Nitrate	588	610	472	465	637	500	525	830	530	600
3	Organic	504	600	590	480	610	545	551	990	452	480
4	None	336	620	580	535	485	465	406	530	448	375
5	Ammonia	504	540	575	470	571	485	450	595	516	425
6	Ammonia	504	535	576	470	533	510	442	680	423	415
7	None	315	535	531	490	484	550	425	630	333	410
8	Ammonia	518	593	510	460	573	545	501	790	484	530
9	None	315	560	576	515	490	520	428	590	347	430
10	Organic	490	580	506	485	662	545	534	855	696	500

Miscellaneous Crops

Five different crops are grouped as miscellaneous crops because none of them fitted well into the other groups.

The only crop of rye grown during these fertilizer experiments was in 1891. Winter rye was sown the fall before, after a crop of oats was harvested and the stubble plowed under. The latter part of the winter was unfavorable to winter crops. Plot 8 was badly injured by insects and was omitted from the records for the year. Nitrate was the outstanding fertilizer for yield of both grain and straw.

Oats and Canada peas formed the crop in 1905, one of the years in which the entire field was limed. This time there was applied one ton per acre of freshly slaked lime. The growth on all the plots that received nitrogen was very rank, and heavy rains caused lodging of the crop and without doubt decreased their yields. Liming improved the relative standing of the best two ammonia plots, 6 and 8, and they were but a little inferior to the nitrate plots. The introduction of the peas as a legume did not raise the standing of the plots without nitrogen.

Oats grown in 1914 as a nurse crop for clover and grasses were cut early for hay, as was the crop of oats and peas just discussed. Nitrate was again the leading nitrogen fertilizer, and ammonia was a little superior to organic nitrogen. One-half of every plot had been limed the previous year, so that conditions were similar to those of 1905.

Japanese millet was seeded in 1913 and cut for hay. The liming of one-half of each plot brought the ammonia plots to the front in yield, with organic nitrogen a good second. This kind of millet was grown in 1916 and was matured and separated into seed and straw. The conditions were somewhat unlike those of 1913, when the millet followed two successive crops of corn. This year, the millet had been preceded in 1915 by an exceptionally good clover crop, the sod of which had been plowed under and on which potatoes had been planted before sowing the millet. Defective seed caused a very uneven stand of potatoes, which were plowed under and the millet substituted.

Estimation of the efficiency of the different nitrogen fertilizers was puzzling. Manure produced the highest yield of seed, while ammonia plots 6 and 8 bore the smallest quantity. But total crop of seed and straw were practically equal. Nitrate plots and organic nitrogen plots bore a similar relation to one another. Plots without nitrogen were nearly as good in yield as those with nitrogen. There may be noted in this crop the influence of the previous clover crop on the nitrogen supply by the narrow gap between the plots without nitrogen and those with it.

TABLE 7—YIELD OF MISCELLANEOUS CROPS
(Pounds per plot.)

Plot	Form of nitrogen	1891		1905*	1913*	1914	1916	
		Rye		Oats and Peas	Japanese Millet	Oats	Japanese Millet	
		Grain	Straw	Hay	Hay	Hay	Seed	Straw
0	Manure	142	328	495	900	265	152	498
1	Nitrate	154	416	690	985	400	121	488
2	Nitrate	134	391	700	915	305	112	458
3	Organic	130	345	670	1005	320	94	550
4	None	107	283	435	730	190	115	470
5	Ammonia	145	385	565	1020	230	103	477
6	Ammonia	102	298	660	1120	290	87	588
7	None	109	341	480	670	205	83	562
8	Ammonia	...	...	690	1220	335	88	586
9	None	109	316	390	670	200	102	538
10	Organic	125	300	650	1020	285	87	547

*Lime applied.

AN ECONOMIC VIEW OF THE EXPERIMENT

A fertilizer experiment, of the kind on Field A, is made to ascertain the effects of definite forms of fertilizers from which may be deduced plans for cropping and manuring that will be economical.

Did the crops grown on Field A use all the fertilizer that was applied each year? The question can be partially answered by calculating the amounts of fertility removed year by year in the harvested crops. Some of the crops grown on these plots were analyzed and numerous analyses have been made of the same kinds of crops grown on other fields of the experiment station. The data have been used to calculate the amounts of nitrogen, phosphoric acid, and potash contained in the crops during the years from 1889 to 1921, including 33 harvests.

The crops are estimated to have removed from each of the plots receiving sodium nitrate, 228 pounds of nitrogen, while they had each received a total of 148.5 pounds of that element, or 79.5 pounds less than the crops removed. The amount of nitrogen carried away from each of the plots that did not receive any was 174 pounds, which is double the deficit of nitrogen on the sodium nitrate plots; therefore it appears that the latter plots received at least as much nitrogen as the crops could use. The crops on other forms of nitrogen fertilizers as a whole did not remove as much nitrogen as those grown on sodium nitrate.

The amounts of phosphoric acid and potash that were applied to these plots were assumed to be more than enough to supply the crops that could be grown with the nitrogen used. The amounts of these elements removed in the different crops have been calculated in order to learn whether there was any shortage of either at any time.

It was found that the heaviest yield of hay in 1910 removed 13.5 pounds potash and 3.7 pounds phosphoric acid; Japanese millet in 1913 carried away 19.3 pounds potash and 2.9 pounds phosphoric acid; clover in 1915 contained 20.5 pounds potash and 4 pounds phosphoric acid.

The yearly application of chemicals contained 12.5 pounds potash and 8 pounds phosphoric acid for each plot. There is no doubt that the latter was supplied in plenty. With regard to potash, the majority of harvests removed much less than was applied; for example, the largest crop of oats contained 7.5 pounds potash, corn removed 9 pounds potash, four successive crops of hay, 1907, 1908, 1909, and 1910, removed 43 pounds potash and 50 pounds were applied. Since potash is not leached readily from the soil, as a rule there was a surplus of it present for the occasional heavy demand.

Measured by crop yields, manure was the superior source of nitrogen in seven of the years and shared first place with ammonium sulfate in one. The crops were hay, potatoes, soy beans, corn and Japanese millet. One condition affected these crops in common. They were growing throughout the summer season and could utilize the manure nitrogen as it became available. The hay crop may not usually be regarded as a summer crop, but in this instance Brooks, in his report for 1899, stated:

> It is perhaps questionable whether much weight should be attached to the yields at the first cutting, since full development was not reached on account of drought. The rowen gives a better basis for comparison.

Sodium nitrate was superior with eleven crops and shared with organic nitrogen once. Its superiority was shown with all the different kinds of crops except Japanese millet, and it may be regarded as the generally efficient nitrogen fertilizer.

Ammonium sulfate was superior in seven harvests, while it shared superiority once with organic nitrogen and once with manure. In five of these seasons, lime had been recently applied.

Organic nitrogen led the other forms in only three harvests, while it shared the lead once with nitrate and once with ammonia. In four of these seasons the rainfall was below normal; while in that in which it shared first place with ammonium sulfate, a dry spring was followed by drenching summer rains, which apparently washed all sodium nitrate down beyond the root level.

Plots without nitrogen produced in 1911 larger yields of corn, both ears and stover, than any of the plots with nitrogen fertilizers. The corn followed a crop

of clover and timothy, the roots and stubble of which had accumulated so much nitrogen that additional nitrogen in fertilizers had no effect. The summer was exceptionally hot and normally moist, which was especially favorable for corn.

In 1921 the plots without nitrogen were again superior in the production of clover hay, the second year from seeding. This unusual result is explained as follows: The new seeding in 1920 consisted of clover, timothy, and red top. In that season the active nitrogen of sodium nitrate and ammonium sulfate pushed forward the grasses which smothered the clover. Grasses were not encouraged in the absence of nitrogen, and the clover gained its foothold, so that its second year's growth on the plots without nitrogen outstripped the grasses on the plots with nitrogen.

The economic possibilities of the application of nitrogen are shown by comparing the average harvest from all plots with nitrogen against the average harvest of all plots without nitrogen. The crops chosen for this comparison were shelled corn, seed oats, potatoes, and hay. These products are standard money crops and have definite market values. The various other crops grown on these plots are important, but are usually consumed on the farm and therefore are difficult to evaluate.

The average gain per plot as the result of applying nitrogen to oats was small, and ranged from only 5 pounds in 1893 to 50 pounds in 1897. During this period oats alternated with soy beans. The first rotation appeared to make additions of nitrogen of little value, but continuous repetition made it necessary. The average result of five harvests was a gain of barely one bushel of oats to pay for applying 4.5 pounds nitrogen. Since the nitrate was, as a rule, the most effective form and at the present time one of the lowest in price, the added nitrogen for oats may be worth while. It should be mentioned that climatic conditions at this experiment station are not favorable to maximum yields of oats.

The application of nitrogen to the corn crop in 1911 gave no gain in shelled corn. This corn crop followed clover and grass. The accumulation of nitrogen in the turf was all that the crop required. The largest gain from nitrogen was in 1906 when corn followed several successive annual crops, which tended to exhaust rather than increase organic matter in the soil. The gain in this year was 177 pounds, or a little more than 3 bushels. Other gains ranged from one bushel to barely two per plot. Corn needs nitrogen when following tilled crops.

Potatoes in 1900, planted on a clover sod, showed an average gain per plot of 62 pounds or about one bushel. Following soy beans in 1904 and Japanese millet in 1917, there were gains respectively of 361 pounds and 243 pounds. These gains would more than pay for 4.5 pounds of nitrogen. Eight crops of hay showed gains from the use of nitrogen which ranged from nothing when the crop was all clover to 201 pounds when grasses constituted most of the harvest.

Keeping up the nitrogen of the soil in this field appeared to depend on the choice of crops and rotations, when the records of Plots 4, 7, and 9 are considered. In 1883, the soil was that of a "run out" hay field. Corn was grown without fertilizer of any kind. These three plots gave an average yield at the rate of 29 bushels of shelled corn and 3700 pounds of stover. Cropped with corn year after year, these three plots without any nitrogen had dwindled in 1889 to 9.3 bushels per acre. Soil nitrogen appeared to be exhausted. These plots in 1899, after ten more crops of various kinds had been grown on them without nitrogen, bore a crop of clover hay averaging 3660 pounds per acre. The next year they produced potatoes at the rate of 209 bushels per acre. After ten more years,

in 1910, these plots bore a crop of mixed clover and timothy hay at the rate of 6730 pounds per acre, followed in 1911 by a crop of corn at the rate of 83 bushels of shelled corn and 5130 pounds stover per acre, which was slightly more than was produced on the plots which had been receiving 45 pounds of nitrogen in fertilizers every year.

The practical aspect of these experiments may be more clearly perceived by expressing the amounts of the fertilizers in pounds per acre. On this basis the rate per acre for each plot was 45 pounds nitrogen, 80 pounds available phosphoric acid, and 125 pounds potash, which is equivalent to 1200 pounds mixed fertilizer containing 3.75 per cent nitrogen, 6.5 per cent available phosphoric acid and 10 per cent potash. This is a heavy application to be made yearly to some of the crops grown on these plots.

Farm manure was used at the rate of 8000 pounds per acre, or about four loads, and was supplemented by 500 pounds per acre of chemicals containing 6 per cent phosphoric acid and 16 per cent potash. The records of this plot show that manure may be advantageously spread thin when reinforced by superphosphate and potash.

The records indicate that for corn, oats, and hay in a suitable rotation, it would be economical to make a reduction in the amounts of fertilizer to be used, and this would necessitate re-arrangement of the experiment.

EFFECT OF LIME WITH NITROGEN FERTILIZERS

Rearrangement of the application of lime in 1919, by dividing each plot lengthwise, permitted a fair comparison of lime with no lime in relation to the different forms of nitrogen.

Two years, 1919 and 1920, supplied the data, with crops of corn and hay. The different nitrogen fertilizers are compared by averaging the crops from the separate plots. The crop from the manure plot is averaged with those from the organic nitrogen plots.

Liming the nitrate plots was ineffective with corn and barely helpful with hay. It notably increased the yield of ears with the corn crops on the organic plots and on those without nitrogen. The hay crop was also improved.

Liming the ammonium sulfate plots increased the yields of both ears and stover with corn, while the hay crop actually exceeded that on the nitrate plots. Red top was the prevailing grass on the unlimed areas, but timothy and clover grew freely on the limed areas and displaced it.

Table 8—Comparison of Limed and Unlimed Areas

(Yields in pounds per half-plot.)

Form of nitrogen	Corn—1919				Hay—1920	
	Ears		Stover			
	Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
Nitrate	255	274	297	310	276	264
Organic	281	232	238	232	262	198
Ammonia	251	223	255	202	324	231
None	201	175	203	202	177	138

These results of the application of lime are due primarily to the chemical reaction between the lime and the acids of the soil. Lessening the acidity favors the growth of the bacteria that change the nitrogen of organic matter and ammonia into nitrates, which are the most available of nitrogen fertilizers.

Another important effect is produced by the reaction of lime with the ammonium sulfate, which forms calcium sulfate, a substance sometimes found to be beneficial and always harmless; while if lime is absent, ammonium sulfate forms other sulfates with the soil minerals, that are often injurious, particularly to clover, timothy, and corn. Several bulletins of this experiment station describe this behavior of ammonium sulfate.

Lime was not applied in uniform quantities every year like the superphosphate and potash but at infrequent intervals in amounts of 2000 pounds or more per acre. Calcium carbonate dissolves very slowly in the soil water, yet the rainfall will gradually carry it down below the surface soil. Calcium sulfate is more soluble than the carbonate, from which it is formed by ammonium sulfate; therefore plots fertilized with ammonium sulfate will lose the benefits of liming most quickly. To show how the effects of liming wore away, a comparison is made year by year between the average yields of the sodium nitrate plots, 1 and 2, and the averages of the ammonium sulfate plots, 5, 6, and 8.

The comparison is graphical in form, with the yields on the nitrate plots set always at 100, while the ammonium sulfate yields are proportional. It is begun with the crop of 1897, though Plot 8 had been limed in 1894. The effect on this had nearly disappeared but its results led to the application of lime to all plots in 1898, and in subsequent applications all plots were treated alike.

The use of different kinds of crops in the experiment was partly responsible for the fluctuations in production on the two sets of plots; but it should be noted that the deepest depressions occurred from three to five years after an application of lime. A positive rise from the depression took place with the application of lime, except in 1919, when it occurred in the following year.

Because agricultural lime in its different forms is a low-priced commodity in comparison with nitrogen fertilizers, it has been customary to apply it at the rate of one ton or more per acre at intervals of several years. The graph indicates that greater efficiency of ammonium sulfate as a nitrogen fertilizer may be secured by more frequent applications of a smaller quantity of lime at a time.

SUMMARY AND CONCLUSIONS

Field A was laid out in 1883 on "run out" hay land and included eleven plots of one-tenth acre each.

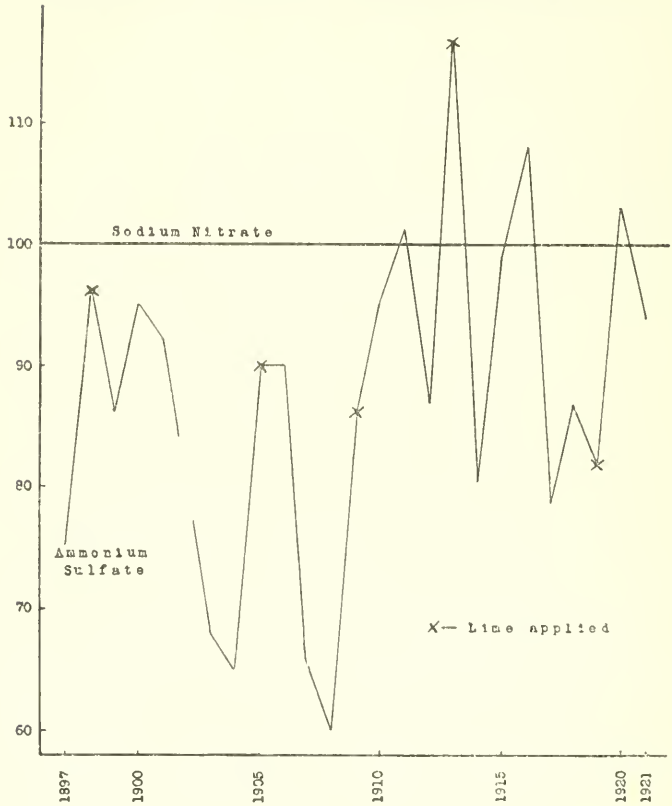
Seven successive crops of corn were grown from 1883 to 1889, to study the effects of different forms and kinds of plant food. The earlier harvests showed potash to be the most needed fertilizer; the later ones indicated that a complete fertilizer had become necessary.

Four standard types of nitrogen fertilizers—nitrate of soda, sulfate of ammonia, dried blood or fish or cyanamid, and stable manure—were compared in 1889, and the comparison was continued with minor changes until 1921.

A variety of crops was grown, and tables show results obtained with oats, soy beans, potatoes, hay, corn, and miscellaneous crops.

When Field A was planned, the use of nitrogen from the air by plants was considered to be doubtful. By 1889, it had been shown that leguminous plants

Effect of Lime as an Accompaniment to Ammonium Sulfate
The yearly ratios between yields of dry matter on sodium nitrate (rated at 100) and on ammonium sulfate are presented graphically.



were using it with the aid of specific bacteria. Early in the present century it was established that nitrogen compounds were formed from air by certain bacteria in the soil, without the presence of leguminous plants.

The early corn crops indicated that "run out" hay land contained a stock of nitrogen which had been accumulated without nitrogen fertilizers.

In 1911, following four successive years of clover and grass, the plots without nitrogen fertilizers led all others in their average yields of corn and stover. In the last year of the experiment, clover hay was heaviest on these plots.

Nitrogen fertilizers were most effective when a tilled crop followed a tilled crop.

Measured by crop yields, sodium nitrate was most frequently in the lead. Ammonium sulfate required the presence of calcium carbonate in the soil to be most effective. When recently limed, the ammonium sulfate plots were virtually equal to the sodium nitrate plots. Farm manure, supplemented with phosphate and potash, excelled several times with crops which made their growth in summer. Organic nitrogen was superior in three seasons.

When this comparison of nitrogen fertilizers was begun, the manufacture of nitrogen compounds from nitrogen in air was impractical because of high cost. At the close of the comparison, such compounds were being made in enormous quantities. At the present time, synthetic fertilizers are being produced from atmospheric nitrogen at such low cost that those used in these experiments may become obsolete in practical agriculture.

The value of Field A to agriculture is its history of the diversity of results. Back of any subsequent work upon it are authentic records of each plot, of which no similar records were to be had when the field was laid out.

There is now nearly ended a comparison of a succession of graminaceous crops with rotations in which such crops alternate with legumes. The experiment is directly dependent upon the records of the plots without nitrogen, from which more nitrogen has been removed in crops than adjoining plots have received in fertilizers.

Field experiments should be planned primarily to afford the investigator an opportunity to test under practical conditions, on a small inexpensive scale, those theories, principles, and processes which have been developed under controlled conditions in the laboratory and vegetation house. To depend upon such experiments to furnish the information and data upon which practices and theories may be based and developed is not justified and is sure to prove disappointing. Where such work has been continued for a long period of years without change, it has resulted in the accumulation of a large mass of records which could not be interpreted in terms of much agronomic value. An intelligent program requires variation in the details of treatment and management in conformity with the changes in economic conditions operating in those relationships.

(The main redeeming feature in the plan for field investigation as developed at Massachusetts State College is the evidence of sufficient courage on the part of those in authority to be willing to change the program from time to time to keep pace with new developments in farm and industrial practice. Had it not been for such courage, the few conclusions possible after this fifty-year period of detailed and accurate work would, no doubt, have proved more limited. F. J. S.)

Publication of this Document Approved by Commission on Administration and Finance
3M-12-32. No. 6992.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 291 DECEMBER, 1932

Two Systems of Feeding Dairy Cows

High Roughage and Low Grain versus Low Roughage and High Grain

By J. B. Lindsey and J. G. Archibald

The amount of grain to be fed to cows is a question of perennial interest to farmers, particularly in a state like Massachusetts where grain is bought outright, while roughage is grown at home. Though much has been written on the subject, it has been largely opinion unsupported by experimental evidence. The experiment here reported was carried out to provide such evidence.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

TWO SYSTEMS OF FEEDING DAIRY COWS: HIGH ROUGHAGE AND LOW GRAIN vs. LOW ROUGHAGE AND HIGH GRAIN FEEDING

By J. B. Lindsey, Research Professor, and J. G. Archibald, Assistant Research Professor of Chemistry

INTRODUCTION

The question of the proper amount of grain to feed to milking cows has always been one of great interest to farmers. Each individual farmer has his own opinion, and many have been the discussions centered around the problem at country store, Grange Hall, and other rural meeting places. Much, too, has been written on the subject in the farm press and elsewhere, both by practical farmers and by extension workers in dairy husbandry. Strangely enough, however, the various expressed opinions have had very little accurate experimental evidence behind them. About twenty years ago the Pennsylvania Experiment Station investigated the problem, but as the amounts of grain fed to two different groups of cows were not greatly different it left considerable to be done.[1]

It was decided, therefore, to conduct a long-time experiment on the subject at this station. This bulletin presents the results of the investigaton, which was commenced October 1, 1928 and brought to a conclusion March 31, 1932, after having been conducted continuously for a period of three and one-half years.

METHODS OF EXPERIMENTATION

The station herd of high grade Holstein cows was utilized throughout the entire period. The number of cows in the herd varied at any given time from ten to fourteen, which were divided equally and as uniformly as possible into two groups, referred to hereinafter as the high roughage and the low roughage group. All individuals were kept throughout the duration of the experiment (or for the length of time they remained in the herd) in the group to which they were originally assigned.

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[1] Note: After the investigation herein reported had been brought to a conclusion and the results had been prepared for publication, the authors received copies of a report* of a somewhat similar investigation that recently had been conducted at the United States Dairy Experiment Station at Beltsville, Maryland.

The method of feeding described therein modifies the old rule of a pound of grain for so many pounds of milk, irrespective of other factors. It takes into account quality of roughage, capacity of the cow for roughage, level of milk production and fat test, and suggests the following rule, recognizing that it is applicable only where silage and a good quality of hay are available. For Jersey cows feed grain at the rate of 0.6 pound for each pound of milk produced above 10 pounds, and for Holstein cows feed 0.4 pound for each pound of milk above 16 pounds. The advantage claimed for this method is that it results in more economical feeding for two reasons: (1) Because cows will get enough nutrients from good roughage alone to provide for the maintenance of their bodies and also for the production of a certain amount of milk; (2) because one pound of grain does not contain sufficient nutrients for 3 pounds of milk. By the old rule, therefore, the low producers were overfed and the high producers were underfed. The modified rule overcomes this objection by regulating grain feeding according to a cow's capacity for roughage as well as by her milk production.

The method seems to have worked out quite satisfactorily but requires modification and care in its use for cows near the upper and lower limits of their production; it is worthy of trial by New England farmers who have corn silage and good quality hay available.

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*Woodward, T. E., Shepherd, J. B., and Graves, R. R. Feeding and management investigations at the United States Dairy Experiment Station at Beltsville, Md. 1930 Report. U. S. Dept. Agr. Misc. Pub. 130. 24 p. 1932.

TABLE 1. —AVERAGE AMOUNTS OF ROUGHAGE* AND GRAIN FED.

(Pounds daily per Cow)

	High Roughage Group		Low Roughage Group	
	Roughage	Grain	Roughage	Grain
Recommended	25.1	6	19.5	11
Fed	24.0	6	19.5	11
Actually eaten	23.7	6	19.4	11

*All roughage reduced to a hay basis and so reported. Because of considerable variations in the lengths of time the various roughages were fed, this was the only feasible method of handling the data.

The rations fed to both groups were of the same general character, the difference between the groups consisting in the proportion of roughage to concentrates. The high roughage group received grain at the average rate of one pound to $4\frac{1}{2}$ pounds of milk, approximately thirty-five pounds of corn silage (November through April) and as much hay as they would clean up. The low roughage group received grain at the average rate of one pound to $2\frac{1}{2}$ pounds of milk, approximately twenty pounds of corn silage (November through April) and as much hay as they would clean up. The amounts of grain were adjusted each month according to the milk yield. The rations in general were adjusted according to Haecker's standard whenever a change was made in the kind of roughage, e. g., from silage to rowen, or from rowen to green feed. Dry cows received 50 per cent in excess of the nutrients required for maintenance. The average amounts of grain and roughage for each group over the entire period appear in Table 1. When silage was not available, rowen and first crop hay were fed in equal or approximately equal amounts except during July, August, and September, when the rowen was replaced by such green crops as oats and peas, millet, and fodder corn[2], five pounds of green feed being substituted for one pound of rowen. The hay was a mixed hay of good quality grown on the station grounds, containing at times considerable clover, but composed for the most part of timothy, red top, June grass, and sweet vernal grass. At any given time all feeds for both groups were from the same original lots. In order to keep the protein level for both groups approximately the same, it was necessary to feed to the high roughage group a grain mixture somewhat richer in protein than that fed to the low roughage group. This was done by varying the proportions of the several ingredients in the two mixtures. The formulas of the mixtures appear below.

	Grain Mixture	
	For high roughage group	For low roughage group
	Per cent	Per cent
Wheat bran	20	20
Ground oats	15	25
Corn meal	15	30
Gluten feed	25	15
Cottonseed meal	25	10

These mixtures contained respectively about 17.9 and 12.8 per cent of digestible protein. The average composition of all feeds used in the experiment is shown in Table 2. Table 3 shows the total and average amounts of dry matter, digestible protein, and total digestible nutrients consumed in each group.

A study of Table 1 shows that while the average daily amount of feed recommended for the high roughage group was slightly in excess of that recommended for the low roughage group (.6 pound more), the amount fed was .5 pound less and the actual amount eaten was .7 pound less. This seeming discrepancy was due to the fact that considerable trouble was experienced from time to time in getting the cows in the high roughage group to eat sufficient roughage to meet their theoretical requirements according to Kellner's standard. A persistent effort was made to overcome this difficulty by offering the cows their theoretical quota of roughage for days at a time, even when it was evident that they were wasting considerable quantities of it, in the hope that in time they would become accustomed to the

[2]It would have been desirable to have had pasture for the cows during the summer, but as none was available within reasonable distance green feed was resorted to. It is not believed that under present farming conditions a system of green crops is economical for the average farmer.

relatively large amount of roughage and the relatively small amount of grain. Some of them did, but more did not, which accounts for the slightly lower feed consumption by this group.

TABLE 2.—AVERAGE COMPOSITION OF FEEDS

(Per Cent)

Material	Number of lots	Water	Ash	Crude protein	Crude fiber	N-free extract	Crude fat
Hay	14	10.5	4.7	8.4	30.4	44.1	1.9
Rowen	7	11.8	6.4	11.8	23.9	42.9	3.2
Corn silage	3	75.9	1.1	2.1	6.0	14.2	0.7
Green oats and peas	3	84.9	1.6	2.6	4.4	6.1	0.4
Green millet	2	79.2	2.0	2.3	6.2	9.9	0.4
Green corn fodder	3	71.7	1.4	2.1	6.6	17.4	0.8
Green soy beans	1	62.9	4.0	6.9	10.1	15.3	0.8
High protein grain	12	11.0	5.2	22.7	7.8	48.7	4.6
Low protein grain	12	11.8	4.2	16.8	6.8	56.0	4.4

Table 3 shows that with respect to amounts of digestible protein eaten the two groups are not far apart, .09 pound per cow daily, or 3.8 per cent, in favor of the low roughage group. Respecting total digestible nutrients, this group ate on the average 1.09 pound, or 6.3 per cent, more daily than did the high roughage group. They ate also .46 pound, or 1.7 per cent, more dry matter daily per cow than did the high roughage group. These inequalities in feed intake are commented on in the general discussion toward the end of the bulletin.

Records Kept

All cows were weighed at the first of each calendar month, the average of two weighings on consecutive days being taken unless the weights differed by more than twenty pounds, in which case a third weighing was made.

All milk was weighed, and a five-day composite sample was taken each month from each cow in milk and analyzed for total solids and fat.

All feeds were weighed for each animal each day and any feed refused was weighed and recorded. All feeds were sampled from time to time and complete fodder analyses were made according to the methods of the Association of Official Agricultural Chemists.

Summaries were made each month and at the end of the year for the whole year, so that cost of milk production at any given time was definitely ascertained.

Careful breeding records were kept and notes were made from time to time on the general appearance of the cows.

RESULTS OF THE INVESTIGATION

General Appearance

A summary appears in Table 4. The low roughage group maintained their general appearance on the whole better than did the high roughage group. This was due probably to the slightly greater intake of nutrients by the low roughage group. With the exception of two individuals, Nos. 35 and 88, which maintained an excellent appearance all through the experiment, the cows in the high roughage group showed a tendency to be rough coated and rather thin.

TABLE 3.—AMOUNTS OF FEED, DRY MATTER, TOTAL DIGESTIBLE NUTRIENTS, AND DIGESTIBLE PROTEIN CONSUMED.

	High Roughage Group				Low Roughage Group			
	Amount consumed	Dry Matter	Total digestible nutrients	Digestible protein	Amount consumed	Dry matter	Total digestible nutrients	Digestible protein
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Hay	74,781	66,929	39,724	3,455	67,204	60,148	35,699	3,105
Rowen	23,561	20,781	12,952	1,918	18,792	16,575	10,330	1,530
Corn silage	64,823	15,622	10,333	681	37,394	9,012	5,961	393
Green oats and peas	17,680	2,670	1,713	340	17,028	2,571	1,650	327
Green millet	10,497	2,183	1,395	154	8,285	1,723	1,101	122
Green Corn fodder	15,158	4,290	2,988	194	13,455	3,808	2,652	172
Green soy beans	235	87	53	13	180	67	41	10
High protein grain	31,950	28,436	22,391	5,729	.....	.....	.....	.....
Low protein grain	.....	.....	.....	.....	59,286	52,290	41,761	7,571
Total	.....	140,998	91,549	12,484	.....	146,194	99,195	13,230
Daily average per cow*	.....	26.64	17.30	2.36	.....	27.10	18.39	2.45

*Obtained by dividing by 5293 and 5394 respectively, the number of cow days in the two groups.

TABLE 4.—GENERAL APPEARANCE OF COWS.

Cow No.	Age at Conclusion of Experiment: Years	Age at Conclusion of Experiment: Months	Appearance: At the beginning or when included in the experiment	Appearance: At the end or when withdrawn from the experiment
High Roughage Group				
35	10	7	Good	Excellent
71	8	3	Good	Good
88	7	2	Excellent	Excellent
98	4	.. (*a*)	Fair	Good
128	3	11 (*b*)	Fair	Good
137	3	7 (*c*)	Fair	Good
139	4	8	Good	Fair
143	3	3 (*d*)	Good	Fair
144	4	4	Excellent	Good
Low Roughage Group				
15	11	6 (*e*)	Good	Good
33	10	6	Good	Good
40	6	11 (*f*)	Fair	Fair
99	5	8 (*g*)	Fair	Good
121	4	6 (*h*)	Good	Excellent
126	5	6	Good	Good
138	4	8	Good	Excellent
141	4	7	Fair	Excellent

(*a*) Age when sold June 17, 1929. Very poor producer.
(*b*) Age when sold September 23, 1930. Aborted and had been a poor producer previously.
(*c*) Age when sold February 16, 1931. Reactor to tuberculin test.
(*d*) Age when sold February 16, 1931. Reactor to tuberculin test.
(*e*) Age when sold February 16, 1931. Old cow getting thin and lame.
(*f*) Age when sold July 15, 1929. Could not get her with calf.
(*g*) Age when sold February 16, 1931. Reactor to tuberculin test.
(*h*) Age when sold February 16, 1931. Reactor to tuberculin test.

Body Weight

Because two-thirds of the individuals were immature when included in the experiment, maintenance of body weight could not be used as a criterion. It has been necessary to compare instead the relative gain in weight of the two groups, care being used to have weights for any one individual at beginning and end represent approximately the same stage of gestation. The weights are shown in Table 5.

With one exception[3] all the individuals gained in weight during the course of the experiment, the older cows making moderate gains, while the younger ones made normal to excellent growth. Taking the data in Table 5 at their face value it would seem that the low roughage ration was somewhat superior to the high roughage ration for maintenance and growth. It must be pointed out, however, that the average time interval between the two series of weights was twenty-seven months in this group while the average time interval for the high roughage group was twenty-two months. Assuming that had the time interval for the latter group also been twenty-seven months they would have continued to gain in weight at a rate equal to the average for the twenty-two month interval, the average individual gain would then have been 124 pounds and the percentage gain for the group 11.5 per cent. The above assumption may not be strictly justifiable, but no better means of adjustment is known and in fairness some allowance should be

[3] This cow was purchased for the experiment and at time of purchase was in show condition, carrying considerably more flesh than it is our practice to have our animals carry. Her failure to gain in weight is attributed to this reason. She was by no means thin when the experiment was completed.

TABLE 5.—CHANGES IN BODY WEIGHT.

Cow No.	Weight in Pounds: At beginning of, or when included in, the experiment	Weight in Pounds: On a comparable date at or near end of, or at time of withdrawal from, the experiment	Gain: Pounds	Gain: Per cent
		High Roughage Group		
35	1020	1070	50	4.9
71	1175	1295	120	10.2
88	1140	1180	40	3.5
98	1000	1145	145	14.5
128	1165	1200 (*a*)	35	3.0
137	1090	1300	210	19.3
139	990	1235	245	24.7
143	1040	1110	70	6.7
144	1065	1060	5 (*b*)	0.5 (*b*)
Averages	1076	1177	101	9.4
		Low Roughage Group		
15	1210	1220	10	0.8
33	1190	1205	15	1.3
40	950	1005	55	5.8
99	960	1225	265	27.6
121	1115	1400	285	25.6
126	970	1060	90	9.3
138	1005	1375	370	36.8
141	1025	1220	195	19.0
Averages	1053	1214	161	15.3

(*a*) Actual weight not available; weight estimated from previous year's records.
(*b*) Loss.

made for the difference in time interval. Even after making this allowance, however, the low roughage group had some advantage insofar as gains in weight were concerned. These data bear out the general observation noted from time to time and referred to on p. 6 that the high roughage group showed a tendency to be rather thin, due probably in part to the slightly smaller amount of feed eaten.

Milk Yield

Milk production records are available for fourteen complete lactation periods in each group. Records of partial lactation periods have not been included because there is no known method of correcting them so that they will be comparable. The complete records as reported in Table 6 have all been corrected to a 305-day basis with proper allowance made in each case for length of time a calf was carried during the lactation.[4]

The corrected daily milk yield per cow was almost exactly four pounds, or 14.4 per cent, more in the low roughage group than it was in the high roughage group. The number of lactations being the same, the total production was, of course, correspondingly higher in the low roughage group. It is to be expected that cows getting a liberal allowance of grain will milk more freely than if on a restricted

[4]These corrections were made by using the factors published by Gaines and Davidson in Illinois Experiment Station Bulletin No. 272, pages 25 and 34, Tables 7 and 8. Correction for age was unnecessary as the average age of both groups was approximately the same throughout the investigation.

allowance. The problem is concerned only in a minor sense with the amount of milk produced, the more important question being the relative economy of production, which is discussed later.

TABLE 6.—DATA RESPECTING MILK PRODUCTION.

	High Roughage Group	Low Roughage Group
Average daily milk yield per cow*.....pounds	27.68	31.67
Total milk yield of each group*.....pounds	118,207	135,244
Dry matter required to produce 100 pounds of milk.....pounds	114	106
Digestible nutrients required to produce 100 pounds of milk.....pounds	74	72
Average length of lactation period.....days	325	311
Average length of dry period.....days	91	81
Average length of time calf was carried during the lactation.....days	182	200
Average number of productive days per calendar year.....days	285	290

*Corrected to a 305-day basis.

The high roughage group was slightly more persistent in milk flow as evidenced by an average lactation period two weeks longer than the average for the low roughage group. This can be attributed almost entirely to a shorter calf-carrying period during the lactation, the difference being eighteen days. The possible significance of the later breeding and resultant shorter calf-carrying period is discussed in the section dealing with reproduction. It may be noted at this point that both groups remained non-pregnant after calving somewhat longer than is usual and hence had somewhat shorter calf-carrying periods during the lactations. The slightly greater persistency in milk yield shown by the high roughage group is completely offset by a longer average dry period, the average number of productive days per calendar year being slightly higher for the low roughage group.

The low roughage group made slightly better use of their feed, eight pounds (7 per cent) less dry matter and two pounds (2.7 per cent) less digestible nutrients being required to produce one hundred pounds of milk.

Feed Cost of Milk Production

The next question that naturally arises relates to the feed cost of production of the milk. This will vary with local conditions and relative costs of roughage and grain, and for any given time and place must of necessity be determined by the individual farmer. During the time this investigation was in progress the relation between grain prices and roughage prices was such that the feed cost of production was practically the same for both systems of feeding. With grain prices as low as they are at present (December, 1932), the low roughage system has an apparent advantage in immediate economy of production. It should be remembered, however, that where roughage is largely home-grown the high roughage system involves a considerably smaller cash outlay. Also, a farmer may be able to raise hay and silage for less than average prices. If so, the difference represents a profit on his labor which should be taken into consideration in calculating costs.

Costs should be figured not on the basis of actual cash outlay but on the cost of

a unit of milk produced. Reasonably accurate production records, such as are kept in herd improvement association work, can be used to ascertain this.

Milk Production from Year to Year

The question is often asked concerning certain methods of feeding and management, "How do the cows hold up from year to year in production?" Unfortunately, only a small number of year to year comparisons are available from this study; five from the high roughage group, and seven from the low roughage group. These have been adjusted to a mature cow basis[6], and the actual and percentage increments or decrements from year to year are shown in Table 7.

TABLE 7.—CHANGES IN MILK YIELD OF INDIVIDUAL COWS FROM YEAR TO YEAR.

Cow No.	Milk Yield* Pounds	Change from Year to Year Pounds	Per Cent
	High Roughage Group		
35	10,345		
	9,784	−561	−5.42
	9,921	+137	+1.40
71	8,139		
	9,370	+1231	+15.12
88	12,593		
	10,466	−2127	−16.89
139	8,890		
	10,575	+1685	+18.95
Average	9,950		
	10,023	+73	+0.73
	Low Roughage Group		
33	12,250		
	13,172	+922	+7.53
99	11,201		
	10,590	−611	−5.45
121	10,458		
	12,077	+1619	+15.48
126	8,592		
	10,031	+1439	+16.75
	11,790	+1759	+17.54
138	10,490		
	13,771	+3281	+31.28
141	8,853		
	9,586	+733	+8.28
Average	10,268		
	11,574	+1306	+12.72

*Corrected to a 305-day, farrow, mature cow basis.

Although both groups maintained their milk yield from year to year, the high roughage group did so only by a very narrow margin, while the low roughage group showed a substantial increase. Had there been available the same number of comparisons for both groups it is possible that there might not have been quite such a disparity between them in this respect. Because of the relatively few records caution should be used in interpreting this result.

[6] The adjustments have been made by using the factors for that purpose published by Turner, Ragsdale and Brody in Missouri Station Bulletin No. 221, page 8, Table 2.

Composition of the Milk

As already noted on p. 6 the milk of all the cows was analyzed regularly for total solids and fat. A summary of the analyses appears in Table 8. Individuality plays such a large part in determining the average fat and solids test of a group of cows that it would not be fair to claim that any differences between the groups are due entirely to the experimental treatment. In addition, therefore, to the averages for the entire groups during the experiment, which are included largely as a matter of record, Table 8 also contains comparative data which show the average test for a corresponding period previous to the commencement of the experiment of such members of each group as were in the herd at that time and the average test for these same individuals during the course of the experiment. These individuals constitute approximately half of each group.

TABLE 8.—COMPOSITION OF THE MILK

	Total Solids (per cent)		Fat (per cent)	
	High Roughage Group	Low Roughage Group	High Roughage Group	Low Roughage Group
Entire herd throughout the experiment	11.77	12.33	3.52	3.81
Cows in herd for a corresponding period previous to the experiment:				
Before the experiment.....	12.14	11.81	3.71	3.58
During the experiment.....	11.70	11.79	3.54	3.62

Taken at its face value the first group of figures in Table 8 indicates some superiority in fat and total solids in the milk from the low roughage group. Part of this is apparent only, due largely to the presence in that group of a young cow (No. 126) that turned out to be an unusually high tester for a Holstein, her milk never testing less than 4 per cent fat and averaging 4.5 per cent over a three-year period. As there was not a corresponding high tester in the other group, part of the difference must be charged to this inequality. However, from the second and third sets of figures in the table it seems safe to conclude that part of the difference between the groups in this respect is due to the experimental treatment. While the fat and solids averages for the low roughage group were practically identical for the experimental period and a corresponding period immediately previous to the experiment, this was not the case for the high roughage group. This group showed a shrinkage of 0.44 per cent total solids and 0.17 per cent fat during the experimental period. These figures, representing a large number of individual tests, give evidence that low grain and high roughage feeding may tend to produce milk of slightly lower test as time passes. It does not necessarily follow that the composition of the milk can be substantially changed by any normal system of feeding.

Reproductive Function

Two of the cases of retained placenta were in an individual that had had the same trouble twice previous to commencement of the experiment. The case of chronic metritis was also of long standing, having developed prior to the beginning of the experiment. Both cows that aborted reacted negatively to the blood test for infectious abortion.

TABLE 9.—DATA RESPECTING REPRODUCTION.

	High Roughage Group	Low Roughage Group
Days after calving before		
Appearance of first heat.....days	53	35
Next conception.....days	142	105
Regularity of oestrum:		
Good.....per cent	33	75
Fair.....per cent	45	25
Poor.....per cent	22	0
Number of services required.....	1.3	1.3
Percentage of breedings from one service.....	69	70
Irregularities:		
Retained placenta.....	3	0
Abortion.....	1 (*a*)	1 (*b*)
Other.....	1 (*c*)	1 (*d*)

(*a*) At 7 months.
(*b*) At 6½ months.
(*c*) 1 case of cervicitis.
(*d*) 1 case of chronic metritis.

It is evident that the low roughage group was somewhat nearer normal in its reproductive function than the high roughage group. This was true especially with regard to the cycle of oestrum and the length of time from calving to the next conception. The condition and weight at birth of the calves produced by both groups is summarized in Table 10.

TABLE 10.—DATA ON CALVES DROPPED DURING THE EXPERIMENT.

	High Roughage Group	Low Roughage Group
Sex distribution:		
Male.....per cent	84.6	60.0
Female.....per cent	15.4	40.0
Average weight at birth*.....pounds	98	98
Condition at birth:		
Very good.....per cent	31	20
Good.....per cent	61	60
Fair.....per cent	8	20

*Corrected for unequal sex distribution; the average birth weight of all Holstein bull calves dropped in the station herd over a long period of years is 8 per cent higher than the average birth weight of Holstein heifer calves dropped in the herd for the same period.

Twenty-eight calves are represented in the summary in Table 10, thirteen in the high roughage group and fifteen in the low roughage group. Average birth weight was the same in both groups. At first glance it would seem, from the standpoint of condition at birth, that the calves in the high roughage group were on the whole more vigorous. However, it must be pointed out that all the "fair" individuals were heifers. It is common knowledge that bulls, as a rule, are more vigorous when born than heifers are, and part of the difference in this respect can probably be charged to the larger number of heifers in the low roughage group.

DISCUSSION OF RESULTS

Viewing the results as a whole, the low roughage group of cows had a rather better record. They looked thriftier, put on more flesh, milked more freely, maintained their production better from year to year, maintained their average test better, and were more nearly normal in their reproductive function.

In searching for a reason for the better showing of this group the most obvious one is the sightly greater food intake noted on p. 5. This difference in intake of nutrients favors the low roughage group and because of it criticism might be made of the conduct of the experiment.

It must be pointed out, however, that the discrepancy is due in some measure at least to an inherent weakness in the high roughage system of feeding which has been brought out by the experiment; viz., that these cows would not, or could not, eat sufficient roughage to satisfy their theoretical requirements when the amount of grain fed was kept down to one pound for each $4\frac{1}{2}$ pounds of milk daily. It is felt also that there must be other reasons for the better showing of the low roughage group. Superiority for milk production of the total digestible nutrients and possibly of the digestible protein in their ration is suggested as another cause. In the high roughage group 24 per cent of the total digestible nutrients and 46 per cent of the digestible protein consumed came from the grain, while in the low roughage group 42 per cent of the total digestible nutrients and 57 per cent of the digestible protein consumed came from the grain. Another factor not to be lost sight of is the additional energy required to digest the extra coarse fodder in the high roughage ration.

It is evident that cows will not produce to the limit of their ability on a high roughage system of feeding. Whether it is economical to have them do so will depend very largely on local conditions as to production and markets, and in a large measure the problem is one for the individual farmer to solve for himself.

If he is situated relatively far from market, with sufficient low-priced land to grow an abundance of rough feed, and if he has big hearty cows accustomed to consume readily large quantities of hay and other roughage; then the high roughage system is undoubtedly the one to adopt. If he is near a good market and the demand for milk is such that he is not unduly penalized for surplus production, if he has relatively little land and that high priced, and if he has cows of the smaller breeds; then undoubtedly liberal grain feeding is the practice to follow.

In between these extremes will be found the majority of New England farmers, and it is believed that in a great many cases the ratio of 1 pound of grain to $3\frac{1}{2}$ pounds of milk is likely to prove the most satisfactory. Each farmer must study his own situation, weigh the facts, and decide for himself.

In conclusion, it must be emphasized that the high roughage system of feeding cannot prove satisfactory unless the roughage is of good quality, which means legume or mixed hay cut early and well cured, and corn silage that is sweet, well eared, and not watery.

SUMMARY AND CONCLUSIONS

This bulletin reports the results of an investigation, three and one-half years in length, on the relative merits of two systems of feeding dairy cows. One of these systems involved the feeding of a relatively large amount of roughage and a relatively small amount of grain; the other involved the feeding of a relatively small

amount of roughage and a relatively large amount of grain. The station herd was divided into two groups which for convenience have been designated the high roughage and low roughage groups. The high roughage group received approximately one pound of grain for each 4½ pounds of milk produced, 35 pounds of silage, and as much hay as they would clean up. The low roughage group received approximately one pound of grain for each 2½ pounds of milk produced, 20 pounds of silage, and hay as above.

All feed was the same in composition at any given time for both groups, except that the grain mixture for the high roughage group was considerably richer in protein in order to keep the intake of protein at about the same level in both groups. In all other respects the treatment of the groups was identical.

Records were kept of general appearance of the cows, live weight, milk production, feed consumption, composition of the milk and of the feeds, and the reproductive function of the cows, including calf production.

The following results have been noted:

1. The cows in the low roughage group maintained their general appearance rather better than did those receiving a relatively large amount of roughage. The latter tended to be thinner and more rough coated.

2. The cows in the low roughage group made somewhat larger gains in weight.

3. The cows in the low roughage group produced more milk on both a daily and a yearly basis. Their lactations were slightly shorter but so also were their dry periods, so that their average productive period per calendar year was slightly higher.

4. The cows in the low roughage group made slightly better use of the feed they consumed as evidenced by the fact that they required 7 per cent less dry matter and 2.7 per cent less digestible nutrients to produce 100 pounds of milk.

5. Feed cost of milk production was practically the same for both groups. The high roughage system, however, involves a smaller cash outlay; and an additional saving may be effected where that system is used if the farmer is able to grow his roughages for less than the current market price.

6. The cows in the low roughage group maintained their milk production from year to year somewhat better than did those in the high roughage group.

7. The low roughage group maintained a uniform milk test as compared with their test previous to the commencement of the experiment, while the high roughage group fell off somewhat in this respect.

8. The low roughage group was somewhat nearer normal in reproductive function than the high roughage group.

The conclusion which has been reached from the results of this experiment is that in order to keep cows looking well and producing somewhere near the limit of their ability, reasonably liberal grain feeding must be practiced. Whether the practice will be economical depends largely on the particular set of conditions prevailing in different localities and on individual farms. With the facts in hand each farmer must make his own decision as to whether he will follow either of the systems outlined in these pages, or possibly a happy medium between the two.

Publication of this Document Approved by Commission on Administration and Finance
4M-1-'33. No 7371

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 292 December, 1932

Carbon Disulfide Emulsion for the Control of the Root-Knot Nematode

By E. F. Guba

Many greenhouse establishments lack the necessary means to sterilize soil with steam or hot water. Even where these methods are practiced with successful results, they are laborious and slow and require expensive equipment. This bulletin considers the merits of carbon disulfide emulsion for controlling the root-knot nematode and its use in combination with certain soil fungicides.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CARBON DISULFIDE EMULSION FOR THE CONTROL OF THE ROOT-KNOT NEMATODE

By E. F. Guba, Assistant Research Professor of Botany

INTRODUCTION

Root-knot, caused by the nematode *Heterodera radicicola* (Greef) Müll., is the most prevalent and destructive disease of greenhouse cucumber and tomato crops in Massachusetts, and the most costly to control. It is common knowledge that soil applications of steam or hot water give control; nevertheless the need for an efficient chemical control is urgent. Because of the fact that formaldehyde and acetic acid lack satisfactory nemacidal value, their use for controlling soil inhabiting fungous parasites has been largely ignored in greenhouse practice. A more extended use of these soil disinfectants in greenhouses cannot be realized in the absence of a satisfactory chemical nemacide.

The merit of carbon disulfide emulsion as a nemacide was discovered by Schaffnit and Weber (7) in Germany. Greenhouse tests by Chapman and Parker (1) in Virginia, and by Gleisberg (3) in Germany, confirmed this discovery. The work in Germany showed that the use of carbon disulfide emulsion can be relied upon to restore normal yields and at a profitable investment. Schaffnit and Weber mixed one part of soap with four parts of carbon disulfide by volume (80 per cent emulsion), and according to their recommendations each square foot of bed received 1.3 to 2.0 ounces of actual carbon disulfide. Chapman and Parker used a commercially prepared 35 per cent emulsion at a dilution of 1-50 in water, and each square foot of bed received about 0.9 ounce of actual carbon disulfide. The merit of carbon disulfide emulsion as a nemacide is thus recognized yet there has been a lack of information that would justify any recommendations to the public on the part of this Station without careful tests in local greenhouses. Information has been needed particularly concerning the best dilution of the emulsion, the rate of application, and other factors which might be expected to have an influence upon its efficiency, cost, and safety under commercial greenhouse conditions.

PRELIMINARY CONSIDERATIONS

Commercially prepared emulsions[1] containing 35 per cent and 70 per cent carbon disulfide were at first compared on a small scale. Each was diluted to make a strength of 1-50 and applied at the rate of 1 gallon to each square foot, equivalent to about 0.9 and 1.93 ounces of actual carbon disulfide. Tomato plants were set in the plots 3 days later and were allowed to grow for two months. The tomato roots in the control plot showed a bad infestation of root-knot while those in the treated plots were healthy. The results were very striking.

The cost of a 70 per cent commercially prepared emulsion at 17 cents per pound in 50-gallon drums is, however, prohibitive in practice, for it means an expense for material alone of $0.034 per square foot or about $1481.00 per acre. A similar homemade emulsion can be made at a cost of $0.009 per square foot, or approximately $392.00 per acre, excluding labor; and if effective would represent an economical method of control. Such an emulsion was prepared to contain 68 per cent carbon disulfide, 26 per cent water, and 6 per cent rosin fish oil soap (No. 9)[2].

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[1] Manufactured by I. P. Thomas & Son, Company, Philadelphia, Penn.

[2] Manufactured by James Good, Inc., 2111 E. Susquehanna Ave., Philadelphia, Penn.

Fresh lettuce roots with attached galls not in excess of $\frac{1}{4}$ inch in diameter were added to nematode infested soil in three 8-inch pots on November 6, 1930. Similarly, fresh tomato roots with attached galls not in excess of $\frac{1}{4}$ inch in diameter were added to another set of three pots. On that date, and 10 and 20 days later, the contents of one pot of each series was drenched with carbon disulfide emulsion of a concentration of 1-50 in water. A few days after the treatment the pots were seeded to tomatoes. The roots were examined on the following April 13 (Table 1). The freedom of the roots from nematode root-knots offered convincing and supporting evidence of the nemacidal value of carbon disulfide emulsion, and the necessary encouragement to justify further tests under commercial conditions of culture. Several experiments have been conducted over a period of three years.

TABLE 1. — CONTROL OF ROOT-KNOT NEMATODE WITH CARBON DISULFIDE EMULSION.

On November 6, 1930, 8-inch pots were filled with soil in which were embedded roots with root-knots attached; the soils were treated the same day and 10 and 20 days later, and then seeded to tomatoes.

Source of Inoculum	Date of Treatment	Root Infestation April 13, 1931	
		Treated	Not Treated
Lettuce roots	11-6-30	Apparently none	Slight
	11-16-30	Apparently none	Severe
	11-26-30	Apparently none	Slight
Tomato roots	11-6-30	Apparently none	Severe
	11-16-30	Apparently none	Severe
	11-26-30	Slight	Severe

GREENHOUSE EXPERIMENTS

The tests were conducted in greenhouse ground beds heavily infested with nematode where, in the absence of sterilization, the crops have proved a complete failure as the data will show. The experiments were located in the north end of one of the greenhouses of Corazzini & Company, and at the Field Station of the Massachusetts Agricultural Experiment Station in Waltham. Tomatoes were employed as the crop plant in every case.

Methods

Materials. — The materials used in the preparation of stock carbon disulfide emulsion and the quantities of each are as follows:

Material	*Volume (Gallons)*	*Weight (Pounds)*
Carbon disulfide	68	680
Rosin fish oil soap	6	54
Water	26	208

The exact amount of stock emulsion needed was calculated in each case according to the area of the greenhouse bed. The required amounts of soap and water were mixed together in a wooden barrel, or similar container, and stirred vigorously with a long-handled shovel. The carbon disulfide was added last, while stirring. The stock emulsion of carbon disulfide was used at various dilutions with water, as reported in each experiment. In some instances commercial 37 per cent formaldehyde and 56 per cent acetic acid were used in combination with diluted carbon disulfide emulsion in the proportion reported in the experiments.

Figure 1. Tomato and Cucumber Roots Severely Infested with the Root-Knot Nematode. The knots are densely inhabited with mature female nematodes which offer a great potential increase in the nematode population of the soil. These roots should be gathered and destroyed to render sterilization more effective.

Preparation of Beds. — The larger infested roots of the old crop were removed when the plants were cleaned out, but in one instance (Table 8) these were left in the ground for comparison (Fig. 1). In most of the experiments three to four weeks elapsed after the removal of the previous crop to permit decay of the roots, but shorter intervals were used in some cases in order to determine to what extent the decay of the roots influenced the effectiveness of the chemical. If the soil was dry, it was wetted well with water a day before treatment.

Application of the Chemical. — Some of the beds were dug over and left rough and then drenched. Others were dug as the chemical was applied. The usual application was at the rate of 1 gallon of diluted emulsion to each square foot of bed, but in some instances more was applied for comparison. The thoroughness of application and penetration in the subsoil are important factors influencing the efficiency of steam or hot water methods of sterilization, and this fact was fully appreciated in the use of chemicals. Walls adjacent to the beds were also drenched. After the beds were treated they were wetted further with water.

Experiments in a Commercial Greenhouse

Spring of 1930. — Four beds were treated with carbon disulfide emulsion, to determine the effect of different concentrations of carbon disulfide emulsion on the control of the root-knot nematode and the consequent yield and income of tomatoes. The stock emulsion was used at concentrations of 1-25, 1-50, 1-75, and 1-100 gallons of water, and applied at the rate of 1 gallon to each square foot of bed. The treatments were made February 21. The roots were well decayed when the plots were spaded in preparation for the treatments.

Potted tomato plants which were grown in steam sterilized soil were set in the beds five days after the treatment. A control plot adjoined each treated plot. Careful yield records were kept. No records of root infestation were made, but examination of the roots when the plants were pulled on July 17, 1930, revealed some root infection in all the treated plots. The plants in all of the treated plots maintained a healthy, turgid growth, produced a good set, and the tomatoes were practically all of first grade. In the control plots the plants produced a poor set, and wilting, which is characteristic of a severe infestation of nematode, was very pronounced. One-half of the yield of the controls was of second grade fruit. The results clearly show the merit of carbon disulfide emulsion in eliminating the nematode as a factor in crop loss (Table 2).

TABLE 2. — EFFECT OF DIFFERENT CONCENTRATIONS OF CARBON DISULFIDE EMULSION ON THE CONTROL OF THE ROOT-KNOT NEMATODE AND THE CONSEQUENT YIELD AND INCOME OF TOMATOES

(Spring Crop, 1930. Commercial Greenhouse)

	Dilution of Carbon Disulfide Emulsion				No Treatment
	1-25	1-50	1-75	1-100	
Cost of chemical for 100 square feet	$ 1.88	$ 0.94	$ 0.59	$ 0.47	
Yield of 100 plants ... pounds	695	719	720	672	403
Increase in yield ... pounds	292	316	317	269	
Gross income from 100 plants at 23 cents per pound	$159.85	$165.37	$165.60	$154.56	$64.48[1]
Increase in gross income	$ 95.37	$100.89	$101.12	$ 90.08	

[1] Since approximately 50 per cent of the crop from the control plot was of second grade, the income from that plot is calculated on the basis of an average of 16 cents per pound.

Spring of 1931. — This test was conducted to compare carbon disulfide emulsion with formaldehyde and to determine the influence of different methods of applying carbon disulfide emulsion on the control of the root-knot nematode and the consequent yield and income of tomatoes. The fall planting of tomatoes was removed on January 16. The chemicals were applied on February 15. One plot received carbon disulfide emulsion as a top drench after the soil had been spaded; in another plot the chemical was applied in the furrows as the soil was being spaded. One bed was treated with formaldehyde alone. Application in each plot was at the rate of 1 gallon per square foot. The beds were planted to tomatoes on February 21. The planting was cleaned out on July 22.

TABLE 3. — COMPARISON OF CARBON DISULFIDE EMULSION WITH FORMALDEHYDE AND THE INFLUENCE OF DIFFERENT METHODS OF APPLYING CARBON DISULFIDE EMULSION ON THE CONTROL OF THE ROOT-KNOT NEMATODE AND THE CONSEQUENT YIELD AND INCOME OF TOMATOES

(Spring Crop, 1931. Commercial Greenhouse)

	Carbon Disulfide Emulsion 1 — 50		Formaldehyde 1 — 50	No Treatment
	Spaded In	Top Drench		
Roots free or relatively free of root-knots.per cent	85 71	72.70	50.00	1.96
Yield of 100 plants.....pounds	502	464	437	178
Gross income from 100 plants at 20 cents per pound	$100.40	$92 80	$87.40	$21.36[1]
Increase in gross income.....	$ 79.04	$71.44	$66.04	

[1] Since approximately 50 per cent of the crop from the control plot was of second grade, the income from that plot is calculated on the basis of an average of 12 cents per pound.

In this experiment, carbon disulfide emulsion was most efficient in the control of the root-knot nematode, and best yields were correlated with the best control of the pest (Table 3). An application of carbon disulfide emulsion while spading the beds, which provided the most thorough drenching of the soil, gave the best results. The check plot yielded an average of 1.7 pounds of tomatoes per plant, largely of second grade, compared with an average of 5 pounds from the best plot receiving carbon disulfide emulsion, representing a difference in gross income of 79 cents per plant. Formaldehyde showed considerable value as a nemacide.

Fall of 1931. — This experiment was conducted to determine the compatibility of formaldehyde and acetic acid with carbon disulfide emulsion, and the influence of these combinations on the control of nematode. Comparison was made with an adjacent plot which was steamed with the pan. The beds were treated on August 14 with diluted chemical at the rate of 1 gallon per square foot. The former spring crop was cleaned out July 22. The fall planting was set August 22. Records of root infestation were made on January 18, 1932 (Table 4).

A combination of 1 gallon of formaldehyde and 1 gallon of carbon disulfide emulsion in 50 gallons of water proved as effective as steam applied by the pan method in combating root-knot nematode, although a difference in yield in favor of chemical sterilization resulted. This might be explained by the fact that the chemically treated plots were favored with better pollinating and growing conditions. The addition of acetic acid to diluted carbon disulfide emulsion completely removed the soap from the emulsion which was apparently the reason why the combination was ineffective. Formaldehyde and carbon disulfide emulsion were perfectly compatible and gave complete control of the root-knot nematode.

TABLE 4. — COMPARISON OF COMBINATIONS OF CARBON DISULFIDE EMULSION AND SOIL FUNGICIDES WITH STEAM FOR COMBATING THE ROOT-KNOT NEMATODE.

(Fall Crop of Tomatoes, 1931. Commercial Greenhouse)

	Steam Pan	Carbon Disulfide Emulsion 1 —50	
		With 1 gallon Formaldehyde	With 1 gallon Acetic Acid
Yield of 100 plants.....pounds	203	244	188
Root infestation..... per cent			
Apparently none.....	100	100	0
Slight.....	0	0	21.42
Severe.....	0	0	78.57

Spring of 1932. — This test was conducted to determine the influence of different rates of application of diluted carbon disulfide emulsion and to compare chemical with steam treatment of the soil in the control of the nematode. The roots of the previous fall crop were dug January 18, 1932, and the soil treatments were applied on February 15. Carbon disulfide emulsion, diluted at the rate of 1 gallon to 50 gallons of water, was used at different rates of application, and the treated beds were set to tomatoes February 22, 1932. Records of root infestation were taken on July 25. The best control of the root-knot nematode was obtained in the steamed plot where but 3.7 per cent of the roots were found to be infested, compared with 21.42 per cent in the plot receiving 1.4 gallons and 33.32 per cent in the plot receiving 1 gallon of diluted carbon disulfide emulsion per square foot (Table 5). In spite of these significant differences in control, the yields offered only a slight and inconsistent contrast. Since a rate of 1.4 gallons per square foot would insure a more thorough wetting and greater penetration than 1 gallon, it is inferred that thoroughness of application is an important factor contributing toward the successful control of the pest.

TABLE 5. — INFLUENCE OF RATE OF APPLICATION OF CARBON DISULFIDE EMULSION ON THE CONTROL OF THE ROOT-KNOT NEMATODE, AS COMPARED WITH STEAM.

(Spring Crop of Tomatoes, 1932. Commercial Greenhouse)

	Steam Pan	Carbon Disulfide Emulsion I — 50	
		1.4 gallons per square foot	1 gallon per square foot
Root infestation..... ..... per cent			
Apparently none.....	96.29	78.57	66.66
Slight.....	2.47	19.64	11.90
Moderate.....	0	1.78	9.52
Severe.....	1.23	0	11.90
Total infestation.....	3.70	21.42	33.32
Yield of 100 plants.....pounds	668	640	657

Experiments at the Field Station

Spring of 1931. — Single and double applications of carbon disulfide emulsion were compared for their control of the root-knot nematode. A 1-50 concentration of carbon disulfide emulsion was used. The basal root clumps of the previous planting were dug out on January 30, 1931. Treatments at the rate of 1 gallon to each square foot of bed were made on February 12 and 19. The treated beds were set to tomatoes on February 26. The roots were examined on August 6

(Table 6). The single treatment with carbon disulfide emulsion proved very effective and the double treatment gave complete control of the root-knot nematode.

TABLE 6. — COMPARISON OF ONE AND TWO APPLICATIONS OF CARBON DISULFIDE EMULSION FOR CONTROLLING THE ROOT-KNOT NEMATODE.

(Spring Crop of Tomatoes, 1931. Field Station)

	Carbon Disulfide Emulsion 1 — 50		No Treatment	
	I — One Application	II — Two Applications	I	II
Root infestation ..... per cent				
Apparently none	95.71	100	0	0
Slight	0	0	67.30	62.50
Severe	4.29	0	32.39	37.50
Yield of 100 plants ..... pounds				
Ones	735	863	654	360
Seconds	293	329	301	265
Total	1028	1192	955	625

Fall of 1931. — The purpose of this test was to determine whether successful control of nematode on one crop, resulting from the use of carbon disulfide emulsion (Table 6), could be relied upon to provide control for the succeeding crop. The plots of the previous experiment were again planted to tomatoes on August 24. The plots were not sterilized, but the roots of the previous crop were cleaned out well, and the top soil to a depth of 6 inches was removed. Records of root infestation were taken on January 19, 1932. In spite of the removal of the roots and the soil, and the fact that excellent control of nematode was obtained on the previous spring crop, a severe infestation developed in the fall planting (Plot B, Table 7). The results show that the eradication of nematode in greenhouse soils cannot be obtained with this chemical and that soil treatments must be repeated previous to each crop in order to realize a profitable yield. Steam or hot water methods of sterilization are no exception. Eradication has never succeeded in commercial practice with the most efficient methods of steaming, and there is no reason to expect better results from chemicals.

TABLE 7. — RELATION OF THE DEGREE OF CONTROL OF ROOT-KNOT WITH CARBON DISULFIDE EMULSION ON ONE CROP TO INFESTATION OF THE SUCCEEDING CROP

(Spring and Fall Crops of Tomatoes, 1931. Field Station)

	Spring Crop		Fall Crop	
	Plot A No Treatment	Plot B Carbon Disulfide Emulsion	Plot A	Plot B
			No Treatment	
	1 application			
Root infestation ..... per cent				
Apparently none	0	95.71	0	0
Slight	67.60	0	25.0	10.93
Severe	32.39	4.29	75.0	89.06
	2 applications			
Apparently none	0	100	0	34.83
Slight	62.50	0	16.85	24.72
Severe	37.50	0	83.14	40.44

Spring of 1932. — In this set of experiments the influence of different rates of application of carbon disulfide emulsion and the effect of removing the roots on the control of the root-knot nematode were studied. The old tomato vines with attached root clumps of the previous planting were removed on January 20. In two of the three beds the smaller roots were carefully removed as the beds were spaded, and in the third they were allowed to remain.

The beds were treated on January 21, 1932, with carbon disulfide emulsion of a 1-50 strength to which formaldehyde was added at the rate of 2/3 gallon to each 50 gallons of diluted emulsion. Treatments were at the rate of two and one gallons per square foot. The beds were set to tomatoes on January 29. The roots were examined for root-knot on June 24 (Table 8).

No yield records were taken, but none of the plants showed evidence of weakness or failure to set during the growing period nor was the grade of tomatoes affected. Infestation was not severe enough to affect the growth or yield. Two gallons of carbon disulfide emulsion per square foot gave better control than one gallon; but like the previous experiment one gallon per square foot removed the nematode as a crop loss factor even when the smaller infested roots were left in the beds (Table 8).

TABLE 8. — Influence of the Rate of Application of Carbon Disulfide Emulsion and the Effect of Root Removal on the Control of the Root-Knot Nematode.

(Spring Crop of Tomatoes, 1932. Field Station)

	Roots Removed on Spading		Roots Not Removed
	2 gallons per square foot	1 gallon per square foot	1 gallon per square foot
Root infestation.. .....per cent			
Apparently none.....	92.0	31.6	16.9
Slight.....	4.8	36.6	70.7
Moderate.....	3.2	26.6	12.3
Severe.....	0	5.0	0
Total infestation.....	8.0	68.2	83.0

Discussion

The experimental results show that carbon disulfide emulsion is an effective nemacide and if used properly can be relied upon to eliminate nematode as a serious factor in crop losses. Tomato plants were used exclusively in these experiments and this fact strengthens the case for carbon disulfide emulsion, since according to Jones (5) the nematode gall of the tomato plant offers greater protection to its nematode population than that of the cucumber or lettuce plant, and in addition bears the resistant "cyst" stage. It is logical to believe, therefore, that carbon disulfide would offer better control when following crops of lettuce or cucumbers than when tomatoes have preceded treatment.

In the experiments reported, the root clump of each plant was dug out of the soil when the old vines were removed from the greenhouse as a means of assisting or rendering more effective the action of the chemical and of reducing the potential nematode population of the soil (Fig. 1). Observations and experiments show, however, that this practice alone offers no control of nematode. Naturally, the smaller infested roots were left behind, but judging from the results in Table 1, carbon disulfide emulsion is apparently nemacidal to small, fresh galls. Soil heating with steam or hot water would appear to be superior to chemicals in its nemacidal effect, especially if the galls possess much root covering tissue. Obviously, the removal of such galls before sterilization should assist materially in the control

of the nematode. It is shown (Table 8) that where the smaller infested roots were left in the soil and carbon disulfide was used at the rate of 1 gallon per square foot, 83 per cent of the roots were infested as compared to 68.2 per cent where the roots were removed. Considered on the basis of the degree of infestation, it could not be shown that the removal of the smaller roots improved the efficiency of the treatment in this experiment.

Nevertheless, judging from the results with carbon disulfide emulsion in commercial practice, the removal of the infested roots and the decay of the smaller roots and attached galls appears to be desirable as a matter of insuring greater efficiency of the chemical. According to Jones (5) galls attached to roots require more time to decay than detached galls. The rate of decay of galls is increased with increases in soil moisture and temperature. In view of this fact, it is desirable to keep the greenhouse beds moist by daily waterings, and as warm as possible between the interval of removing the old plants and the time the chemical is applied. The results of the writer's experiments show good control of nematode with carbon disulfide emulsion applied three weeks after the removal of the old planting without introducing the needed moisture and temperature conditions to hasten decay of the roots in that interval. One more week elapsed before the new planting was started. Good control of nematode was obtained when one day elapsed between the removal of the old crop and the application of carbon disulfide emulsion (Table 8) but this was influenced measurably by the rate of application.

Nematodes exist as deep in the soil as the roots extend, and it is not uncommon to find lettuce, cucumber, and tomato roots 30 inches deep in the subsoil. In Florida, the root-knot nematode may be found at a depth of 36 inches, according to Godfrey (4), and in greenhouses they occur fully as deep. Any treatment used to sterilize the soil must be applied with the object of reaching the majority of nematodes or the effectiveness of the treatment will be greatly diminished. The thoroughness of wetting the soil with chemical has a significant influence upon its effectiveness as is borne out in Table 6 where it is shown that two applications of carbon disulfide emulsion applied a week apart gave complete control, while after one treatment 95.71 per cent of the roots were free from infestation. A greater volume of chemical in one application is also more effective, for 1.4 gallons of diluted carbon disulfide emulsion per square foot yielded 78.57 per cent roots free of infestation, as compared to 66.66 per cent from 1 gallon (Table 5); and 2 gallons gave 92 per cent clean roots as compared to 31.6 per cent from 1 gallon (Table 8). In no instance, however, when the rate of application was 1 gallon per square foot, was nematode a factor in crop loss. At that rate of application, increases in gross income of $90.08 to $101.12 (Table 2) and of $71.44 to $79.04 (Table 3) were obtained per 100 plants above that of the same number of plants in the control plots.

The yields from the use of carbon disulfide emulsion were essentially similar to those where efficient steaming was practiced, and this, in general, was correlated with the degree of control of the root-knot nematode. Since a concentration of 1-50 of carbon disulfide emulsion applied at the rate of 1 gallon per square foot has given good control and has restored normal yields, this formula is recommended for those growers who desire to use this chemical.

Carbon disulfide emulsion has given satisfactory results when tested under commercial conditions of culture for combating nematode. Its use, however, has given no control of soil inhabiting plant pathogenes; neither according to the writer's experiments, has it manifested any killing effect on weed seeds. For the control of soil-borne plant pathogenes in greenhouses, the use of formaldehyde has heretofore received some recognition. Doran (2) has shown a similar value from

acetic acid at less expense. Each was used in combination with carbon disulfide emulsion, but only formaldehyde made an effective and compatible combination (Table 3). Judging from the results shown in Tables 3 and 4, formaldehyde may be regarded as having considerable nemacidal value, but acetic acid none. These results appear to be confirmed by the reports of Watson (8, 9) to the effect that formaldehyde when applied in the dosage ordinarily used for the control of fungous diseases gives very good control of the root-knot nematode in seed beds in Florida. Observations of its use in greenhouses in Massachusetts show that alone it does not offer satisfactory control of nematode, although the results in Table 3 are exceptional. In some of the experiments a concentration of 1 gallon of formaldehyde in combination with 1 gallon of stock carbon disulfide emulsion in 50 gallons of water was employed; but successful control of soil inhabiting fungous parasites can be obtained at a concentration of 2/3 gallon of formaldehyde, as has been brought out from the results of many tests at the Field Station.

To qualify as a good nemacide, a chemical must be (a) effective in eliminating the nematode as a crop loss factor, (b) harmless to the soil for plant growth within a reasonable interval after application, (c) easy to apply, and (d) non-injurious to man. Of over thirty chemicals tested by Newhall (6), many of which had been previously considered in earlier investigations, none was entirely satisfactory being objectionable chiefly on account of cost, inefficiency, and unsatisfactory methods of application. Newhall found that pure carbon disulfide used at the rate of 100 gallons per acre was almost as good as the best chemical treatment, i. e., a mixture of napthalene flakes and Cyanogas, on the basis of plant yields. He did not use carbon disulfide emulsion.

On the basis of the writer's experience and that of most growers, the objections to the chemicals used by Newhall should not necessarily apply to carbon disulfide emulsion. However, carbon disulfide possesses that disadvantage of being harmful to man. Prolonged exposure to the gas causes severe headache, dizziness, and vomiting. It increases the heartbeat, and owing to this effect persons having any heart weakness are cautioned not to use it. Otherwise, application is practical, quicker, and under many conditions less expensive than steam sterilization. The harmful features may be largely overcome by the exercise of certain precautions such as shifting the help at the end of five hours, and taking care to provide all the ventilation possible.

Once an infestation of the root-knot nematode appears, its eradication seems impossible no matter how efficient the soil treatment. In spite of the complete absence of visible signs of root-knot at the end of a crop, sufficient potential infection to cause a heavy root infestation and a yield failure on the succeeding crop escapes the action of heat or chemicals (Table 7). Where the practice is to grow two warm temperature crops such as cucumbers or tomatoes each year, the greenhouse beds must be treated before each crop, otherwise the root-knot disease will render unprofitable any investment in the crop. For this reason, it would be more economical in the end to install the permanent tile system of steam sterilization if the greenhouse establishment is permanent and if steam is available, since the expense for chemicals equals a substantial part of an investment in a tile installation. If the use of chemical is objectionable on account of its harmful effect upon men, then sterilization by the use of steam or hot water is advisable.

Carbon disulfide emulsion appears to be the most satisfactory chemical nemacide yet discovered and should find particular use in greenhouse establishments not equipped with efficient systems of steam or hot water sterilization, or where the grower for lack of time finds it more practical and desirable to use chemicals instead of steam or hot water. On the basis of the results here reported, many

growers have used carbon disulfide emulsion on a commercial scale. Their results have been very satisfactory in some instances and very disappointing in others. The most important factors contributing to the poor results have been lack of thoroughness of application and failure to remove the larger infested roots of the old planting when cleaning out the beds, and subsequently to allow time enough for the smaller roots to decay before treatment. The results of the writer's experiments show that the success of carbon disulfide emulsion as a nemacide depends chiefly upon the removal of the old roots and the thoroughness of application. Unless these requirements can be complied with in commercial practice, the use of chemicals is a futile and wasteful expense.

RECOMMENDATIONS

If the grower desires, or is obliged to resort to, chemical soil treatments he should first decide on the choice of materials. If nematode is the only crop loss factor, carbon disulfide emulsion should be used at a concentration of 1 gallon of stock to 50 gallons of water. If fungous diseases alone are responsible, formaldehyde should be used at a concentration of 2/3 gallon to 50 gallons of water. If both fungous diseases and nematode root-knot are factors contributing to the failure of the crop, formaldehyde (2/3 gallon) and carbon disulfide emulsion (1 gallon) should be used in 50 gallons of water. Application should be at the rate of 1 gallon of diluted chemical to each square foot of bed. At this rate of dilution and application, the expense for chemicals used to sterilize 10,000 square feet would be about as follows:

Carbon disulfide emulsion, alone....	$90.00
Formaldehyde, alone.....	70.00
Carbon disulfide emulsion and formaldehyde combined.....	160.00

To calculate the number of gallons of carbon disulfide emulsion needed, the area to be sterilized is divided by 50. This quotient is multiplied by .68 and the product obtained is the number of gallons of carbon disulfide required. To convert gallons to pounds, multiply by 10. The quotient obtained by dividing the area by 50 is multiplied by .06, and the result obtained is the number of gallons of rosin fish oil soap required. This result is multiplied by 9, representing the weight in pounds of each gallon of soap, to obtain the number of pounds of soap needed. To calculate the number of gallons of formaldehyde needed, the area to be sterilized is divided by 75 and the result is multiplied by 8, representing the weight in pounds of each gallon of formaldehyde. Since the chemicals are sold by weight only, it is necessary to know the number of pounds of each required when giving the order.

Preparation of the Beds for Treatment

The roots of the previous planting should be carefully cleaned out and destroyed, and the beds should be kept moist by frequent watering for at least two weeks to assist in the decay of the smaller roots in the soil. Since fresh roots are likely to offer protection to the nematodes against the action of chemical, some decay of the roots is considered desirable before the soil is treated. It is a rather common practice in Massachusetts greenhouses to grow crops of lettuce or radish in the fall and early winter months. The low growing-temperatures for these crops inhibit the activity of the nematode, and root infestation is usually either lacking or not important enough to warrant soil sterilization. In such a rotation of crops, it would be best to delay the use of chemical until 7 to 10 days before planting the spring crop of cucumbers or tomatoes.

Figure 2. Drenching Greenhouse Beds with Carbon Disulfide Emulsion as the Soil is Being Spaded. This is the ideal method of application. It insures both thoroughness and penetration. On a small scale the chemical is diluted in 50-gallon barrels and applied with pails.

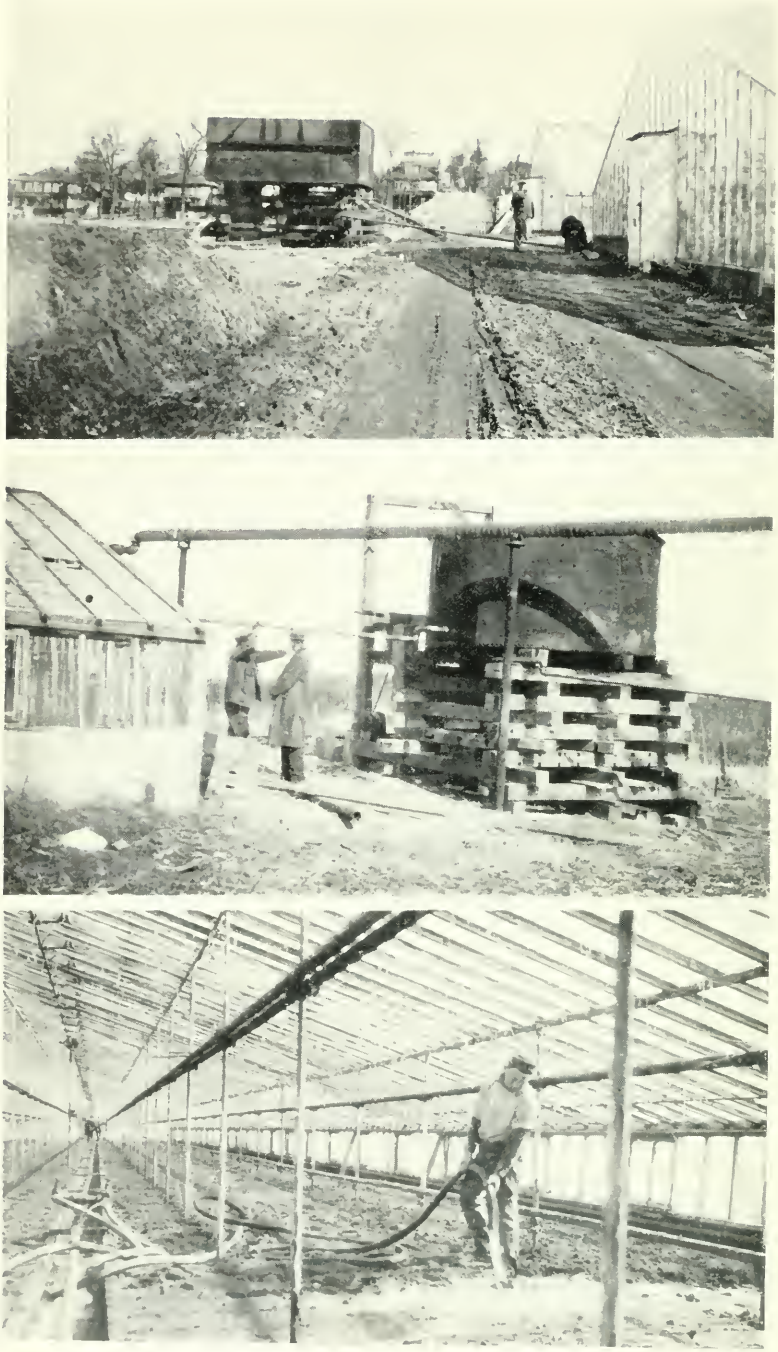

Figure 3. On a Large Scale it is More Practical to Prepare Large Quantities of the Chemical and Either Pump or Gravitate it Into the Greenhouse.

Some means must be provided for agitating the diluted chemical. Top: Tank of 5500 gallon capacity; Middle: Tank of 3000 gallon capacity; Bottom: Unsatisfactory method of application. The chemical runs off to the low level and puddles. It should be applied while the soil is being spaded.

Preparation of Carbon Disulfide Emulsion

A stock emulsion of carbon disulfide is prepared by first mixing together the required amount of soap and water, then adding the carbon disulfide. The water should not be cooler than 60° F.; otherwise the soap will not readily dissolve. Any amount of stock emulsion can be made by multiplying the total number of gallons wanted by .26, .06, and .68, the results representing water, soap, and carbon disulfide in gallons, respectively. Thus, to make a 50-gallon barrel of stock emulsion, 13 gallons of water, 3 gallons of soap, and 34 gallons of carbon disulfide are required.

Application of Chemicals

One gallon of stock emulsion is added to 50 gallons of water and stirred, and this diluted emulsion is applied at the rate of 1 gallon to the square foot of bed. If formaldehyde is warranted, 2/3 gallon is added to each barrel of diluted emulsion. If the chemicals are diluted in barrels, pails are used to apply the solution (Fig. 2). If a large tank is used, the solution may be run out into the beds by gravity through lines of hose, or by pressure through an irrigation system (Fig. 3). The solution must be agitated frequently.

The volume of the tank must be known in order to determine the number of gallons of concentrated chemicals needed to make the proper strength. The volume of a cylindrical tank in cubic feet is determined by multiplying .7854 by the square of the diameter of the tank and this result by the height. The volume of a rectangular tank is determined by multiplying the width by the length by the height. In either case, the result is then multiplied by 7.5 (representing the number of gallons contained in 1 cubic foot), to obtain the capacity of the tank in gallons. Since a 1-50 concentration of carbon disulfide is to be used, the capacity of the tank is divided by 50. The result represents the number of gallons of stock carbon disulfide emulsion needed. If formaldehyde is used alone or in combination with carbon disulfide emulsion, the volume of the tank is divided by 75 (2/3-50 or 1-75) and the result represents the number of gallons of formaldehyde needed.

Treatment should begin in the far end of the greenhouse. The soil should be in a moist condition and the beds should be dug over as the chemical is applied to insure thorough soaking of the soil. It may be convenient to treat the soil in sections corresponding to the areas between posts. The number of barrels of chemical required is determined and this amount is used for each section in the greenhouse. After the house has been treated in the manner described, the beds should be wetted further with water. If carbon disulfide alone is used, the beds may be planted in 6-7 days. If formaldehyde is used, an interval of 10 days may be necessary, especially in cold weather. The safety of the beds for planting may be determined by setting out a few plants; if the plants manifest no sign of injury after 24 hours, the beds should be safe to plant.

Caution

Prolonged exposure to the carbon disulfide gas causes severe headache, dizziness, and vomiting. It increases the heartbeat, and therefore persons having any heart weakness are cautioned not to use it. The harmful features may be overcome by shifting the help at the end of five hours, or by engaging the help for not more than five hours each day until the work is completed. The men should be cautioned to provide all available greenhouse ventilation during application. Cool circulating air furnishes a more desirable atmosphere than warm, stagnant air. The stock emulsion of carbon disulfide should be located outdoors or in a well-ventilated spot in the greenhouse, and the men should be cautioned to avoid its

vapors as far as possible. The pure chemical is highly inflammable and explosive and for this reason the men should be cautioned against smoking or lighting matches when using it.

SUMMARY

In greenhouses, soil treatments with carbon disulfide emulsion have given good control of the root-knot nematode and have restored normal yields. A stock emulsion containing 68 per cent carbon disulfide, 26 per cent water, and 6 per cent rosin fish oil soap was diluted in water to make a 1-50 concentration and applied to the soil at the rate of 1 gallon per square foot.

The cost for chemical materials is approximately nine-tenths of a cent per square foot.

Where soil inhabiting fungous pathogenes are also present, the addition of 2/3 gallon of formaldehyde to the above formula is recommended.

Removal of the infested roots when the houses are cleaned out, decay of root material remaining, and thoroughness of application contribute much to the effectiveness of carbon disulfide emulsion in controlling the root-knot nematode. A delay of at least 2 to 3 weeks after the old crop is cleaned out before treatment, during which interval the beds are kept moist and warm, assists in the decay of the old roots. A further delay of one week after treatment is necessary before planting.

Exposure to carbon disulfide for more than five hours at one time may cause illness and this is an objection to its use. Suggestions are offered for avoiding this danger.

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Publication of this Document Approved by Commission on Administration and Finance.

3M-1-'33. No. 7307

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 293 MARCH 1933

Annual Report

For the Fiscal Year Ending November 30, 1932

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION — 1932

INTRODUCTION

F. J. Sievers, Director

The year 1932 marks the fiftieth anniversary of the Massachusetts Agricultural Experiment Station which was provided for by legislative act and founded in 1882. In common with similar institutions established at about the same date in several other states, the Massachusetts Station has a history covering a half century of service to the American people. The influence of this service on the control of insect pests, the prevention and cure of plant and animal diseases, the better utilization of farm products, the more scientific management of soil, the more systematic and economic feeding and handling of plants and animals, and in general the better management of the entire farm has had a profound expression in the inauguration of greater efficiency in agriculture and therefore, indirectly, in all industry. Increased efficiency as a rule results in the establishment of a so-called higher standard of living and a consequent demand for products and services beyond those required for a bare existence. In agriculture it has resulted, also, in a decrease in the labor necessary to maintain the same volume of production, thus affording an opportunity for the employment of this released labor in other industries and thereby providing for the many so-called luxuries of which the automobile, radio, good roads, better housing and heating facilities, and more liberal provision for education are good examples. For the enjoyment of luxuries a certain amount of leisure is required, and fortunately for the American public, the demand for luxuries and the leisure and income necessary to enjoy them kept fairly uniform pace. Industry boomed, jobs were plentiful, confidence was abundant, and credit unexcelled. Recently, however, when these major factors, which require equilibrium for our successful operation, became unbalanced or disproportionate we experienced an upset in our entire social and economic structure, with the result that at present many of us find ourselves either with more leisure than we can afford, or with more luxuries than our income can support. This fundamental weakness in our social and economic relationships can be permanently corrected only by recognizing the basic causes and dealing with them boldly and without fear or prejudice. This country is adequately supplied, yes, if not oversupplied, with all of the essentials of life. There is no universal lack of food, clothing, shelter, and, last but not least, of human energy ready and willing to apply itself. It is quite generally agreed that we suffer as individuals because of inadequate distribution of an abundant supply of these essentials. Food is not available where hunger exists. Clothing and good shelter are not accessible to those suffering from exposure. But most fundamental of all is the lack of proper distribution of labor or of the opportunity for all willing workers to make a living. To right this condition requires not only courageous research, but a program free from bias.

Of all agencies organized for public service there is none which should be better equipped as regards experienced personnel than the agricultural experiment stations. These institutions, because of their habit and experience in approaching without partiality problems requiring research, and also because of their record

of achievement in fields to which their energies have been directed in the past, should qualify to give aid in the development of a solution for our present problems of depression. There are already evidences that a constructive program based on research is desired. It is not unreasonable to assume that the general public is ready to place the same confidence in results gained by experiment stations in this field that the farmer has, in discoveries in the field of Agriculture. It is a project worthy of our foremost consideration.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

Factors Affecting the Price of Eggs. (A. H. Lindsey.) Revised correlation analysis shows that the price level is the most important factor affecting the annual average price of eggs. For nearby eggs the annual average price decreases 5.68 cents for each 10-point decline in Snyder's index of price level. An increase of 100,000 cases in Boston receipts lowers prices 1.5 cents. For western eggs in the Boston market a 10-point decline in price level lowers the price 4.95 cents, and an increase of 100,000 cases in receipts lowers the price for this grade 1.4 cents.

Further refinement of the influence of various factors at different periods of the year is being carried on covering 12 years of data instead of the original shorter period of 6 years.

Forecasting devices worked out for estimating April average prices from January 1 and for estimating November average prices from June 1 have been found to predict future prices quite accurately.

Work similar to the study of egg prices has been started on factors affecting prices of live and dressed poultry.

Competitive Factors Influencing the Supply of Market Milk and Cream. (A. H. Lindsey.) A survey was completed of milk supplies in all important secondary markets outside of the Boston Metropolitan area. Information was obtained as to percentage of Massachusetts supply, consumption of grade A and pasteurized milk, price conditions, and policies in closed and open markets.

Some time was spent in gathering data from several milk distributors in or near Worcester. For the five distributors visited, preliminary figures on daily milk consumption for the month of April are as follows:

1928		1930		1932	
Number of Families	Quarts	Number of Families	Quarts	Number of Families	Quarts
229	350	322	506	377	548
1,494	1,939	1,822	2,380	1,569	2,133
.....	.....	994	1,367	1,245	1,714
2,003	2,768	2,153	2,821	2,134	2,906
1,284	1,790	1,841	2,563	2,468	3,312
5,010	6,847	7,132	9,637	7,793	10,613
Average per family per day	1.37		1.35		1.36

Shipping Massachusetts Apples. (A. H. Lindsey and A. A. Brown.) This investigation was initiated with the realization that the production of apples in Massachusetts is increasing at such a rate that within a few years Massachusetts

growers must depend on other than local markets. It was desired that the study should bring out the best methods of putting the apples on the more distant markets. The largest apple shippers in the State were visited in the survey. The experiences of these men in shipping apples were studied in detail; such as the comparative advantage of rail and truck shipments, packaging, grading, and methods of contract with motor carriers. Case studies were made of freight bills and of many cases in which legitimate and illegitimate charges were made against the grower or shipper. The reports show that considerable saving could be made by proper routing, and a knowledge of freight tariffs and tariff rules. It is intended to carry on further investigation of the markets next fall.

Recreational and Forestry Uses of Land. (David Rozman.) This project has been completed and the manuscript presented for publication. It points out the place of recreational and forestry uses of land in working out a balanced program of land utilization for the Commonwealth. The investigation indicates that, largely as a result of the abandonment of farm land, about one-third of the total area in towns with a population of less than 10,000 is owned by non-residents. In the towns situated near the coast and in some inland towns the land owned by non-residents is utilized to a great extent for recreational purposes. However, most of the abandoned farm land held by non-residents is represented by idle acres covered with brush and inferior woods. Although the indications are that a considerable amount of the present area of idle land will be taken in the near future for part-time farming and recreational uses, the major part of it will have to be devoted to the growing of trees under the control of both public institutions and private owners.

Marketing of Milk Secondary in Markets of Massachusetts. (David Rozman.) This study, initiated in the spring of 1932, deals with the analysis of marketing problems arising largely from changing conditions of milk supply in secondary markets of Massachusetts. The field work was carried on last summer in three cities situated outside of the Metropolitan area of Boston: Gardner in Worcester County, Attleboro in Bristol County, and Newburyport in Essex County. The data obtained in these cities include information on sources of milk supply and condition of marketing machinery, covering the practices and price plans of producers, distributors, dealers, cooperative organizations, and other distributing agencies.

Consumer Demand for Eggs. (Lorian P. Jefferson.) This project is nearing completion. Much of the tabulation is done, and a considerable portion is in manuscript form.

Changing Methods of Wholesale Distribution of Perishables. (Lorian P. Jefferson.) This project becomes increasingly more timely as distributors continue to seek better and less costly methods of marketing perishables and as new distributing agencies enter the field. It is evident that a process of decentralization is taking place in many places and in particular products. The warehousing of chain-store products is becoming a matter of districts, rather than states or larger regions. The Atlantic and Pacific chain, for example, now maintains several more warehouses in New England than formerly. The wholesale distribution of meat in Boston shows this tendency to decentralization, there being now several points at which meats are received and distributed.

Changes include certain new methods of handling credit and different methods of payment for goods. The growing importance of the traveling jobber, trucker, itinerant jobber, peddler — all these names being applied to the same agent —

is one of the outstanding features of the changes taking place in distribution. This is characteristic of no particular section of the country, and many are the efforts on the part of wholesalers and regular jobbers to control or eliminate this competition with their business. New England wholesalers seem not to suffer greatly from one aspect of this method that is found in other sections, where the traveling jobber buys directly from the grower and sells the product in the market where it would otherwise have been handled by the regular trade.

These aspects of the problem have received some attention, but all must have further investigation.

Analysis of Market Prices for Massachusetts Vegetables. (H. B. Rowe.) This project, begun in 1930, includes the analysis of annual and weekly variations in prices for eight leading vegetables on the Boston market: asparagus, cabbage, carrots, celery, cucumbers, spinach, squash, and tomatoes. Daily price and supply data have been tabulated for the ten-year period 1922–1931. From these data annual and weekly series have been compiled. Conventional methods of price analysis have been used in isolating and measuring the most important relationships explaining price variations. The study has now been practically completed through these stages for each vegetable except cabbage and cucumbers, on which some further analysis is required. A beginning also has been made in preparing the results for publication.

Results include the determination of fairly reliable relationships between prices, supply, and seasonal variation in demand for asparagus, bunched and cut carrots, Pascal and white celery, spring spinach, squash, winter and summer greenhouse tomatoes, and field tomatoes. For each of these products the analysis has furnished a very good explanation of the principal price variations which have occurred during the period included in the study. Also it has been possible to measure the relative importance of receipts from local farms and carlot arrivals as price determinants. In general, local supplies and trend have been the most important factors influencing year to year variations in prices for these products during the period since 1922. Likewise, supplies from local sources and normal seasonal changes account for the major price variations within the season. These relationships appear to have remained practically unchanged throughout the period. In the case of summer and fall spinach, results have been mostly negative in character, apparently due to the wide range of quality covered by available quotations. Results obtained from the project thus far contribute materially to an understanding of the market situation for the vegetable-producing industry of Massachusetts, since they provide definite information regarding price movements and their causes. Such knowledge permits a more reliable interpretation of current market developments by producers as a basis for production and marketing plans. Furthermore it gives a more dependable basis for outlook work and shows the more important items which should be covered in current market reports.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness.) A study of the effect of humidity on evaporation from apples in storage at various temperatures was started in the fall of 1931. Based on the first year's operation, it is apparent that humidities of 70 and 75 per cent cause considerably more evaporation than a humidity of 88 per cent at all temperatures. It was found, however, that the

difference in rate of evaporation at various humidities was greater at high temperatures. The study is being continued during the present season in an attempt to narrow the range of humidities used and determine the lowest humidity which can be safely used without causing shriveling.

Fertilizer Distributors. (C. I. Gunness). A fertilizer attachment was developed for a tobacco transplanter, which would apply the relatively large amount of fertilizer used in the Connecticut Valley and place the fertilizer in bands on both sides of the row of plants. Tobacco was planted with fertilizer applied at different depths and different distances from the row in a test carried out and reported by the Department of Agronomy.

Test of Low-Lift Pumps. (C. I. Gunness.) Additional pumps were tested at the Cranberry Station during the past season. The result of the tests made during the past three years will be published at an early date.

DEPARTMENT OF AGRONOMY

A. B. Beaumont in Charge

Pasture Experiments. (A. B. Beaumont and E. F. Gaskill.) Experiments in the improvement of upland pastures by top-dressing with fertilizers have been continued. The results of 1932 are in general accord with those reported in recent years and summarized in Bulletin 282 published recently.

Work is in progress on the question of form of nitrogen best suited to our pasture conditions. Indications to date are that nitrates, ammonium salts, urea, and calcium cyanamid can each be used advantageously under certain conditions. Experiments with cyanamid have shown that when it is applied in amounts above 200 pounds per acre, a more or less transitory "burn" of grasses and clovers occurs, regardless of the season of the year when applied; but this effect is not considered a sufficient reason for not using this material.

Legume Variety Tests. (J. L. Haddock, A. B. Beaumont and M. C. Darnell, in cooperation with Division Forage Crops and Diseases, Bureau of Plant Industry, U.S.D.A.)

Alfalfa. The highest-yielding varieties for 1932 were as follows:

1929 seeding: Hardigan (4.91 tons), Kansas, Arizona, Utah, and Ontario.

1930 seeding: New Mexico (4.75 tons), South African, California, Argentine, and Oklahoma.

1931 seeding: Hardigan (4.63 tons), Argentine (4.63 tons), New Mexico (19010), New Mexico (19011), and Grimm.

Red Clover. Nineteen strains of red clover were seeded in 1931, and two cuttings were harvested in 1932. The results were similar to those reported last year; namely, that the northern-grown American strains outyielded the European. Tennessee (19002) gave the highest yield (3.10 tons).

Vetch. In the test seeded in the fall of 1931 with rye as a companion crop, the highest yield of vetch alone was from Smooth (0.702 tons), followed in order by Oregon Hairy, Common Hairy, Hungarian, and Oregon Common. In the 1932 spring seeding with oats, the best yield of vetch alone was from Smooth (1.07 tons), followed by Oregon Pearl, Common Hairy, Hungarian, and Oregon Common.

Field Peas. Peas were seeded with oats as a companion crop in 1932. Golden Vine gave the best yield (0.807 tons) of peas alone, followed in order by Chang, O.A.C. 181, Multiplier, Common, and Austrian Winter.

Soy Beans. In the test of 1932, several of the varieties which gave low yields in previous years were discarded as being unsuitable for forage under conditions here. Some new varieties were included in the test. The highest-yielding 10 varieties were: Mukden (new 1932) (2.59 tons hay), Wea, F.P.I. 50536 (new 1932), F.P.I. 63242-2 (new 1932), Dunfield, Harbinsoy, Manchu, F. C. 03654-A, Mansoy, F.P.I. 53933-3B (2.33 tons). Rows were 36 inches apart in 1932, 30 inches in previous years.

Field Experiments with Onions. (M. E. Snell and A. B. Beaumont.)

Fertilizer ratios. The field experiments with lime and fertilizer ratios were continued with no radical changes. This completes three years' records with onion sets, which have proved better adapted to the work than seed onions. The past season, the 4-12-8 (organic) and the 4-12-4 ratios (these figures refer to percentage of NH_3, P_2O_5, and K_2O) were the only ones which yielded higher than their 4-8-4 check plots. The 6-8-8, 4-8-8, 4-12-8 (inorganic), and the 2-12-8 ratios were again poorer than their check plots.

Over the three-year period the 4-12-4, 4-12-8 (organic), and the 4-8-4 (with 2-0-0 nitrate top-dressing) gave slightly higher yields than their 4-8-4 check plots. The 6-8-8, 2-12-8, 4-8-8, and 4-12-8 (inorganic) were all inferior to their check plots. The 6-8-4, 8-16-8, and 4-7-4 (with 2-1-0 fish top-dressing) were about equal to their check plots. Application of lime, in excess of three tons, gave an increase in yield of 5 to 10 per cent for the three-year period. When the lime was withheld and the phosphorus doubled with a 4-8-4 and a 4-12-4, the yield was increased about 10 per cent. When 600 pounds per acre or 1200 pounds per acre of superphosphate were supplied in addition to the 4-8-4, and lime was applied annually for five years at the rate of 1000 pounds per acre instead of in three 1-ton applications over a period of seven years, the increase was 21 and 27 per cent respectively. However, the same applications of superphosphate applied with 500 pounds of lime annually, gave but slight increase over the three 1-ton applications without the extra superphosphate.

Onion set experiment. Last year some preliminary work was done in an attempt to determine methods of getting maximum yields of a desired size of set for planting. Also, the effect of the conditions under which they were grown on the keeping quality of the sets was studied. In these tests 50 pounds of seed per acre, 500 pounds per acre of a 4-12-8 fertilizer, and seed distributed over a two-inch-wide row proved the most satisfactory of the rates tried. The most desirable size of set, 1/2 to 3/4 inch, showed least loss in storage from sprouting, decay, and moisture loss. This size sprouted less than the largest size and decayed less than the smallest two sizes. The lighter seedings and the wider rows showed less loss than the heavier seedings and narrower rows. There was little decay where 500 pounds per acre of a 4-12-8 fertilizer were used.

During the past season more extensive work was done. Four fertilizer levels were used; namely, 500 pounds per acre of a 0-12-8, 2-12-8, and 4-12-8, and 1000 pounds of a 4-12-8. The rates of seeding were 30, 40, and 50 pounds per acre, and the seed was distributed over one-, two-, and three-inch-wide rows with the 500 pounds per acre of the 4-12-8 fertilizer; but two-inch rows were used on all other fertilizer treatments. It was again clearly shown that there is a balance between the food supply and the population, which must be maintained in order to produce maximum yields having a high percentage of a desired size. Forty pounds of seed per acre were adequate with 500 pounds of the 2-12-8, but 50 pounds were needed with 500 pounds of the 4-12-8; 1000 pounds per acre of the 4-12-8, even with a high rate of seeding, supplied too much plant food for a good crop of sets. Five hun-

dred pounds of the 0-12-8 did not give a high yield of either total sets or sets of the desired size; but gave a very high percentage of sets of the desired size, especially with 30 and 40 pounds of seed per acre. In general, 30 pounds of seed per acre were not enough for best results, and the three-inch rows seemed to give better opportunity for development than the narrower rows. Several of the plots yielded over 12,000 pounds per acre of sets of the 1/2- to 3/4-inch size.

Onion Breeding. (M. E. Snell.) This project was continued during the past summer as previously, except for one change in technique. Previously two types of inbreeding had been used. In one, designated as "mass fertilized," all bulbs of each selection were planted close together and just before flowering were surrounded by a netting-covered frame which permitted fertilization among bulbs of the same strain. In the other, known as "self fertilized," each flower head was given a separate covering. Since the two methods seemed to give very similar results, and the former was the more expensive, it has been discontinued.

The seed from the inbred strains, which were crossed a year ago was planted, and a few more cross-matings were made this year. A good crop of bulbs was produced and is being housed in the new storage which was recently completed. This storage should greatly facilitate the work by permitting bulbs to be carried over for breeding purposes, which was not possible with the former facilities.

Field Experiments with Tobacco. (A. B. Beaumont and M. E. Snell.)

Cropping systems. Results of eight years (1924-1931) of experiments on the effect of cropping systems on the yield and quality of tobacco have been summarized for publication in bulletin form. Cover crops were in general beneficial. Of those studied, red top (*Agrostis alba*) was the most, and timothy (*Phleum pratense*) the least beneficial. The highest yield was produced where tobacco was grown continuously with fertilizer and a cover crop of red top, but the best quality of tobacco was produced where manure was used as a supplement to the fertilizer. Tobacco grown in rotation with other crops was low in yield and poor in quality.

In the season of 1932 some changes were made in the cropping systems, including the substitution of oats for rye as a cover crop. The concentration of the nitrogen in the fertilizer used was raised from 4.1 per cent (used 1924-1931) to 5.0 per cent. Red top cover again produced the highest yield (1907 pounds) of all cover crops used, but was slightly surpassed by the manure supplement with no cover. In comparison with no-cover (check) plots, oats, timothy, and rye cover crops depressed the yield in the order given. The yield from the rotation plots was of the same low order as in previous years. The addition of sodium nitrate and calcium nitrate to certain rows of tobacco in the rotation plots did not increase yield but did raise the nitrate content of the soil to a high point. The addition of dried peat in a similar way increased the yield of tobacco.

Form of nitrogen. The old experiment on single forms of nitrogen was modified in 1932. One half the fertilizer nitrogen was supplied from cottonseed meal and the other half from each of the following carriers: sodium nitrate, ammonium sulfate, urea, and calcium cyanamid. The standard fertilizer mixture containing nitrogen from cottonseed meal, sodium nitrate, and calurea was used as a check. In case of tobacco following tobacco, calcium cyanamid and the standard mixture produced the highest yields, followed closely by ammonium sulfate, urea, and sodium nitrate; but after timothy cover or sod, the order was standard mixture (highest), ammonium sulfate, urea, sodium nitrate, and calcium cyanamid.

A new experiment on different proportions of organic and inorganic nitrogen

for tobacco was started in 1932. The organic nitrogen was supplied by cottonseed meal, and the inorganic nitrogen by a mixture of equal parts of sodium nitrate and ammonium sulfate. The fractions of organic nitrogen were 1/8, 2/8, 3/8 and 4/8 of the whole. Comparison was made with the standard mixture. The highest yield (1954 pounds) was obtained with 1/8 organic nitrogen and 7/8 inorganic, followed by 4/8, 3/8 and 2/8 organic. All mixtures yielded more than the standard mixture. Since organic nitrogen is generally assumed to have an especially favorable influence on quality of tobacco, it will be necessary to await the sorting records for these treatments before they can be properly evaluated.

The experiment on different total amounts of nitrogen was discontinued in 1932.

Method of applying fertilizer. Prof. C. I. Gunness of the Agricultural Engineering Department modified the transplanting machine used in these experiments so that fertilizer could be placed by the machine at the time of setting tobacco. The fertilizer was placed in bands 3 inches wide at each side of the plant and 1 inch from it. The standard broadcast application of 3500 pounds per acre was compared with machine application of 4/8, 5/8 and 6/8 of the standard amount of fertilizer. The average yields of tobacco (pounds per acre) were as follows:

Machine Application		Broadcast (Check)	
4/8 Standard application	1846	Standard application	1822
5/8 Standard application	1732	Standard application	1855
6/8 Standard application	1861	Standard application	1881

Comparable experiments were conducted on several private farms of the vicinity. Results obtained thus far from these experiments are similar to those obtained on the station plots. On account of the possible residual effect of fertilizers used in previous years, it will be necessary to continue this experiment several years on the same field.

Distribution of Nitrogen in the Tobacco Plant. (W. S. Eisenmenger.) Tobacco plants were grown in nutrient solutions for about one month. They were then divided into four groups of fifty plants each. Two groups received the same complete nutrient solution — one growing in normal light, the other growing in complete darkness. From the other two groups nitrogen was withheld — one in the light, the other in darkness. The plants were continued thus for eleven days. At the end of this period all were harvested and divided into roots, stems, mid vein and residual leaf portion. They were kept frozen until they were analyzed for total and water soluble nitrogen, a - amino acids, ammonia, amides, protein, peptid, humin, and nitrate nitrogen. The results indicated that much of the nitrate is reduced in the aerial portion of the plant, at or near the mid vein. Darkness increased the nitrate and a-amino acid in the plants and decreased the leaf weight. Withholding nitrogen lowered the dry weight of roots and stem.

The results of this investigation have been accepted for publication in the *Journal of Agricultural Research.*

Toxicity of Aluminum for Tobacco. (W. S. Eisenmenger.) Tobacco plants were grown in nutrient solutions for slightly less than two months. The solutions were renewed every second day. For two days they grew in a complete nutrient solution (Knop's), and on the succeeding two days the solution was the same except that phosphates were withheld and aluminum citrate was added in varying concentrations — 0, 2, 5, 15, 30, 50, 70, 85, 95, 98, and 100 per cent of .006 Mol. Definite toxicity effects were indicated in the dry weights of top and roots.

Similar toxicity effects are being determined for the seedling stage of soy beans,

corn and buckwheat in single-salt solutions. Also the ameliorating effects of Ca, K, OH and Mg ions in separate cultures are noted.

Magnesium Requirement of Crops. (A. B. Beaumont and M. E. Snell.) The crops grown in the field in 1932 were alsike clover, buckwheat, soy beans, corn, and oats. Oats on magnesium-deficient plots exhibited a marked chlorosis of intervenous leaf tissue in the early stages of growth, but lost this sympton in later stages. Buckwheat and corn developed mottled chlorotic leaves in the late-growth stages. Only in case of buckwheat was the yield better on plots which received magesium sulfate than on magnesium-deficient plots.

Top-dressing Grasslands with Fertilizers. (A. B. Beaumont and M. E. Snell.)

Fertilizer ratios. This experiment was expanded in 1932 to include a wider range of ratios. In both the old and the new portions of the experiment the results show a definite response to increments of potash only. The highest yield was from fertilizer having a ratio of 3:3:8 ($N:P_2O_5:K_2O$). High nitrogen failed to rank as high as in the past four years, probably because a second cutting could not be made on account of the drought of the latter part of the summer.

Forms of nitrogen. In a new experiment in the top-dressing of an old mowing (meadow) with different commercial forms of nitrogen, the highest yield was obtained from nitrate of soda, followed by ammonium sulfate, urea, and calcium cyanamid in order. Here, again, on account of dry weather no second cutting was available, and this may have affected the order of the results.

Assimilation of Fixed Nitrogen by Grasses and Clovers. (A. B. Beaumont, W. S. Eisenmenger and W. J. Moore.) Five species of grasses and clovers used for forage were grown in sterilized and unsterilized solution cultures which contained sodium nitrate, ammonium sulfate, or urea in addition to the requisite minerals. From the weight of dry matter produced and from the chemical composition, it was concluded that nitrogen was assimilated most completely in the form of nitrate by the grasses, and in the form of urea by the clovers. In the later stages of growth, ammonium sulfate and urea became toxic to both grasses and clover. In the unsterilized cultures the roots became dark and decayed, but in the sterilized cultures they remained white and sound. In explanation of the darkening and decay of the roots, the narrowing of the C-N ratio by the accumulation of unassimilated nitrogen in the roots is suggested. The addition of calcium carbonate to the ammonium sulfate solution maintained the reaction near the neutral point, but this did not prevent the injurious action on the roots, nor did it materially increase the growth of the plant and the assimilation of nitrogen.

Nitrification of Castor Pomace, Soy Bean Meal, and Other Organic Materials. (M. H. Cubbon.) Nitrate nitrogen accumulation in an acid soil of low fertility as influenced by the above materials was studied in the laboratory over a three-month period. Readings were taken at 10-day intervals. The nitrogen content of the castor pomace samples varied from 4.36 to 5.80 per cent. In three months' time 75 to 100 per cent of the nitrogen in castor pomace and soy bean meal was nitrified. High oil content (10.24 per cent in castor pomace and 18.62 per cent in soy bean meal) slightly hindered but did not prevent nitrate accumulation. Nearly half the nitrogen in such organic materials as peanut shell meal, garbage tankage, ground peat, "soil sponge," and "hyper humus" changed to nitrate in three months. Peanut shell meal caused a decided depression of nitrates for the first month. Nitrate accumulation from sulfate of ammonia proceeded at average level after the first month. Apparently a month is necessary in this soil for nitrate accumulation to be noticeable.

Effect of Varying Amounts of Moisture and Organic Materials on Soil Nitrates. (M. H. Cubbon.) Nitrate nitrogen was produced in large quantities in potted soils which had been treated with different (and large) amounts of domestic peat and manure. The moisture content was purposely varied in different pots. Nitrates increased with increase of moisture up to about 35 per cent. Nitrate nitrogen disappeared from the soil, or was greatly reduced, when turnips began to grow vigorously. Soils which received excessive amounts of manure (80 tons), or peat equivalent to 20 tons of manure, maintained a relatively high nitrate nitrogen content throughout the growing season. (This is part of a study of factors affecting "dark center" of turnips, in cooperation with the Department of Olericulture.)

Fine Turf Grasses. (L. S. Dickinson.) Further studies have been made regarding the desirability of pre-seeding fertilization of newly built or newly seeded turf areas, and a check experiment has been conducted to verify the results obtained in 1931. Nitrogen, phosphorus, and potash were applied singly and in combinations prior to seeding with Kentucky bluegrass and Colonial bent. The check experiments were conducted in deep boxes, placed out of doors and unprotected. The results obtained again indicate that on normal soils pre-seeding fertilization with anything but superphosphate or a single phosphorus carrier is unnecessary. Also, that stronger young plants are obtained without pre-seeding nitrogen and potash, and that the plants will more economically use fertilizer applied as a top-dressing when they are from 60 to 70 days old. This project was made possible by the New England Greenkeepers' Association.

The plots maintained in cooperation with the United States Golf Association, and the nine-year-old lawn plots on one of the regular campus lawn areas, are the only plots that are now being maintained, due to the decrease in funds.

A new project, made possible by Brague Inc., has been started to determine the advisable amounts of peat to be mixed with various types of soil to improve the physical condition. This involves a study of methods of determining, easily and quickly, yet with practical reliability, the physical strength of soil samples. A study is being made, also, of methods of establishing definite soil standards to use in comparative work.

DEPARTMENT OF BACTERIOLOGY
Leon A. Bradley in Charge

Nitrogen Fixation in the Presence of or as a Result of Legumes Versus Non-Legumes. (J. E. Fuller.) Additional studies have been made to determine the activity of nitrification and carbon-dioxide evolution, for the purpose of comparing these activities with nitrogen fixation in the same field in which previous studies have been made. Dried blood and ammonium sulfate respectively were added to the soil, and the rate of nitrification of these substances was determined. Carbon-dioxide evolution was determined from soil samples to which oat straw had been added. All of the experiments were carried out in pots in the laboratory. The soil samples studied represented two lots, one lot having been collected before the field was plowed in the spring, and the other in the fall after the crops had been harvested. No influence was observed, on the part of the legume crop as compared with the non-legume crop, on nitrification or cellulose decomposition. A paper describing the study in detail has been accepted for publication in *Soil Science*.

Influence of Temperature on the Nitrate Content of Soil in the Presence of Decomposing Cellulose. (J. E. Fuller and L. H. Jones.) This study was

carried out in cooperation with the Department of Botany. The results of the experiments have been published (*Soil Science* 34:337-351, 1932), and reference may be made to the published paper for details of the study.

Application of the Soil Plaque Method for Determining Mineral Deficiencies in Massachusetts Soils. (J. E. Fuller.) The method depends on the growth of Azotobacter as an indicator of the presence in the soil of minerals essential to the growth of crops. The results obtained from the soils studied indicated that the method cannot be depended upon for determining the deficiency of available phosphorus under the conditions existing in the field from which the samples were taken. It was observed that the soils did not contain sufficient phosphorus to support Azotobacter growth, even though the field from which the samples were taken had produced satisfactory crops. Further studies are being made with soil samples collected from more widely distributed areas.

Bacteriological Studies of Dried Milk Powders. (J. E. Fuller and R. L. France.) Several samples of dried milk powder were examined for the presence of the tubercle bacillus in order to determine the safety of the powder for feeding calves. Some of the samples were from milk powder dried by the roller process; others, from milk powder dried by the spray process. The latter, being easily soluble in water, were made into solution and inoculated into guinea pigs. The animals of this group were observed for a month and then killed. The milk powder dried by the roller process was only partially soluble in water, so the powder was mixed with other food and fed to guinea pigs. The animals of this group were observed for two months and then killed. Both groups of guinea pigs appeared to be healthy throughout the periods of observation. The weights of all of the animals showed gradual increase. Autopsies did not show any evidence of tubercular infection in any of the animals. The experiments indicated that the milk powders studied did not contain tubercle bacilli. These results agreed with those obtained by other investigators.

Udder Infection in a Cow. (J. E. Fuller and R. L. France.) The udder infection studied occurred in a cow of the experiment station herd. An organism was isolated from the milk and also from the udder when the cow was killed. The blood serum of the cow agglutinated the organism to a titer of 1 to 1,280. The study will be reported more in detail at a later date.

Laboratory Service. (R. L. France.) Following is a list of the number and types of examinations made by the laboratory during the past year:

Milk (bacteria counts)	1,160
Water analysis	123
Miscellaneous:	
*Butter fat	197
*Milk solids	7
Baby foods	12
Throat swabs	10
Chlorine	4
Yeast	2
Powdered milk	1
Anaerobes	1
Food poisoning	1
TOTAL	1,518

*Analysis made by P. H. Smith, Feed Control Laboratory.

This is an increase of 270 examinations over the previous year, due mostly to bacterial and chemical examinations of milk. This phase of the service has increased yearly, and the laboratory is providing a valuable service to milk producers, dairymen and local health inspectors throughout the Valley.

The number of water analyses has shown a decrease during the past year. This is probably due to the fact that the laboratory is unable to make a sanitary survey of the supplies examined. Without this survey it is impossible to offer constructive suggestions in the care of polluted supplies.

The stock of legume cultures has been kept intact and these were furnished to farmers requesting them for inoculation of leguminous plants.

Upon request of the Horticultural Manufactures Department bacterial examination of samples of a new baby food were made.

Bacterial counts of milk samples held under different cooling methods were made for the Dairy Department.

The Indol Tolerance of the Colon-Aerogenes Group of Bacteria as a Possible Means of Differentiating Fecal and Non-Fecal Strains Occurring in Drinking-Water Supplies. (R. L. France.) Preliminary work on this project has been completed and accepted for publication in the *Journal of Bacteriology* under the title, "Bacterium coli in rural privately owned water supplies."

The results obtained in this investigation suggest that dependence on the Standard Methods procedure alone for determining the sanitary quality of drinking water, especially from privately owned supplies of unknown history, results in too many of the samples being condemned. The need of supplementary differential tests is indicated, but results do not justify the recommendation of any particular test or group of tests.

In an effort to derive a satisfactory test, work is being done to determine the indol tolerance of strains of the Colon-aerogenes group of bacteria. Results to date do not justify any statement regarding sharp differences among strains.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Black Root-Rot of Tobacco. (W. L. Doran.) Tobacco was grown for the tenth successive year in plots last limed in 1923. In 1932, there was no black root-rot in plots not limed, the soil of which has a pH value of 5.2, but the disease was moderately severe in adjacent limed plots, the soil of which has a pH value of 5.9. The average yields of tobacco per acre in 1932 were 1906 pounds in plots not limed and 1559 pounds, or 18 per cent less, in plots limed. The persistence of the effects of lime on black root-rot and yields of tobacco is indicated by the fact that, with lime last applied in 1923, loss in yield in limed plots (as compared with yield in plots not limed) has been as follows: 10 per cent in 1924, 45 per cent in 1925, 43 per cent in 1926, 35 per cent in 1927, 23 per cent in 1929, 25 per cent in 1930, 16 per cent in 1931, and 18 per cent in 1932. The sorting record of the crop of 1931 (the latest crop sorted) showed that lime applied in 1923 was still resulting in impaired quality as well as reduced yields. The fire-holding capacity of the crop of 1931 was not injured by lime, however.

In pot experiments, infection of tobacco by *Thielavia basicola* (Berk. and Br.) Zopf was much reduced or, more often, entirely prevented by ammonium thiocyanate applied to soil at the rate of 900 pounds per acre. This rate of application was as effective in preventing infection as were heavier applications. It resulted, however, in soil toxic to tobacco for 18 weeks, although not for 25 weeks, after

treatment. The length of time toxicity persisted was not shortened by the supplementary use of ferric chloride.

Calcium cyanide applied to soil at rates up to 1800 pounds per acre did not prevent infection of tobacco by Thielavia. Heavier applications reduced the severity of infection without increasing soil acidity, but were toxic to plants.

Brown Root-Rot of Tobacco. (W. L. Doran.) When this disease developed following timothy in a cropping system, it was usually more severe in clay soils than in sandy soils. The addition of timothy to a soil was sometimes beneficial to tobacco, the benefit being greater in sandy soils than in clay soils. In general, timothy when followed by brown root-rot of tobacco was less harmful in sandy than in clay soils; and timothy when it did not result in brown root-rot of tobacco was followed by better growth of tobacco in sandy than in clay soils.

Disease Resistance of Potato Varieties. (W. L. Doran.) The varieties Green Mountain, Katahdin, and Foster's Rust-proof were compared. There was no late-blight and there was little or none of the virus diseases. The season was dry and there was much injury of Green Mountain and Katahdin by drought, tip burn, and insects (aphis and leafhopper). Under these conditions, Foster's Rust-proof was much more resistant and long-lived than either Green Mountain or Katahdin.

Downy Mildews of Cucumbers and Lettuce. (W. L. Doran.) Downy mildew of cucumbers (*Peronoplasmopara cubensis* (B. & C.) Clint.) was not observed here in 1931, but it appeared on August 18 in 1932. This is the latest recorded date of its first appearance here in any year. An account of investigations of this disease by the writer has been published recently in Bulletin 283.

It was found that resin has a markedly fungicidal effect on *P. cubensis*. A stock solution was made of resin 5 parts, wood alcohol 5 parts, and potassium hydroxide 1 part. This was then diluted with water so as to contain resin in the proportions indicated below. Infection of cucumber plants, sprayed with resin solutions previous to inoculating with *P. cubensis*, was entirely prevented by resin 1:150 and reduced to only a trace by resin 1:200. There was no injury to cucumber plants by resin 1:150, although they were slightly injured by resin 1:100.

Downy mildew of lettuce (*Bremia lactucae* E. Regel) was severe on the variety Bel-May in greenhouses in April 1932, although this variety had been previously considered relatively resistant.

The resistance of certain varieties of lettuce was shown by the average number of plants which became infected out of each 100 plants inoculated with *B. lactucae*. These were as follows: Dreer's Wonderful, 25; Sutton's Golden Ball, 24; Rosy Spring, 3; Dreer's Iceberg, 1; Loos Tennis Ball, 0; Loos Tennis Ball (Vilmorin's), 0.

Germination of the conidia of this fungus was prevented when the conidia, in water, were placed on micro-slides which had been sprayed with resin 1:100. A 0.25 per cent solution of sodium tetraborate (borax) similarly used was likewise effective in preventing germination. Anhydrous sodium carbonate was ineffective at the concentrations used.

With over 90 per cent of these conidia germinating in water, less than 10 per cent germinated in a 1 per cent water solution of the exudate from cut stems of lettuce plants.

Sporulation of *B. lactucae* was entirely prevented by dusting infected plants with sulfur dust. Copper-lime-arsenic dust was nearly as effective.

Eggplant Wilt. (E. F. Guba, Waltham.) Growth of Verticillium in culture occurred at a range of 50°-95° F., with the optimum at 78°. The best growth of

eggplant occurred at a soil temperature range of 77°-95° F., and most infection at 77°. No infection occurred at soil temperatures of 55.4° and 95° F.

When aluminum sulfate was used to acidify the soil, no infection occurred at pH values below 5.0; and when inoculated sulfur was used, there was slight infection at pH 4.0-4.2. Aluminum sulfate gave more consistent control of wilt at the low values than sulfur.

Results of field applications of aluminum sulfate and sulfur were disappointing and revealed no justification for artificial soil acidification in the field as a means of control. The culture of eggplant on naturally acid sod land offers the best means of controlling wilt. The investigation is concluded with this report.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.)

Tomato leaf-mold. Extensive tests reveal the lack of immunity among any varieties of tomatoes to attack by *Cladosporium fulvum* Cke., but some varieties show a mild resistance as expressed in slight spore production, belated infection, and yellow spots, in contrast to a rich growth of the fungus on foliage of susceptible varieties. The varieties Maincrop, Up-to-Date, Norduke, and Norton were most resistant. Maincrop and Up-to-Date produce small, smooth tomatoes and set heavily; Norduke and Norton produce large, rough tomatoes and set very poorly under glass. Reciprocal crosses of these varieties have been obtained for future study. Riverside X Up-to-Date, Stonnors M. P. X Up-to-Date, Maincrop X Up-to-Date, and E. S. 1 X Up-to-Date, crosses made by Dr. W. F. Bewley of England for resistance to Cladosporium, are similar to Maincrop and Up-to-Date in cropping characters and resistance. Of these four hybrids, Stonnors M. P. X Up-to-Date and Maincrop X Up-to-Date were most resistant. These hybrids have been crossed further with Norton and Norduke in the hope of developing a suitable greenhouse tomato which is, at least, less troubled by the disease than the standard varieties now being grown.

A paper dealing with the relation of environment to the development and control of tomato leaf-mold under glass is in preparation.

Effect of hydrocyanic acid gas on cucumber plants sprayed with copper fungicides. Cucumber plants were always injured when gas followed copper fungicides containing calcium hydroxide, sodium hydroxide, or sodium carbonate. Even when the alkali compound was reduced to produce neutral mixtures, injury resulted after gas. Injury occurred regardless of whether the gas was evolved from Cyanogas or from sodium cyanide, or whether chemical hydrated lime, milk of lime, or lime water was used in the preparation of Bordeaux.

Injury was always correlated with water soluble copper which increased with the amount of alkali present in the spray.

Residues of Bordeaux on glass acted upon by gas yielded soluble copper and hydrocyanic acid gas, and these occurred in a fairly constant ratio. The toxic salt is presumably calcium cuprocyanide $CaCu_2(CN)_4 5H_2O$.

If spraying greenhouse cucumbers with Bordeaux is warranted, fumigation with hydrocyanic acid gas should precede the copper treatment, or cyanide fumigation should be abandoned in favor of tobacco fumigants. The investigation is concluded with this report.

Control of the root-knot nematode in greenhouses with carbon disulfide emulsion. This investigation has been completed and the results published in Bulletin 292.

Eradication of Nematodes in Greenhouse Soils by the Use of Chemicals. (L. H. Jones.) In further experiments, using a mixture of liquid orthodichlorobenzene adsorbed in diatomaceous earth and calcium cyanide, nematodes were eradicated from soil in six-inch flower pots that was heavily inoculated with large

nematode galls from tomato roots. Orthodichlorobenzene adsorbed by diatomaceous earth and lacking calcium cyanide has little nemacidal value. Calcium cyanide alone will materially reduce the injury caused by nematodes, but the addition of orthodichlorobenzene prolongs the nemacidal activity of the cyanide and has effected eradication.

The most effective mixture from the standpoint of eradication without subsequent injury to seed germination and plant growth proved to be, by weight: 1 part orthodichlorobenzene (12.5 grams) adsorbed by 4 parts diatomaceous earth (50 grams) and then mixed with 2 parts calcium cyanide (Cyanogas) (25 grams). Two treatments of the soil are necessary with this mixture, with an intervening interval of a week, and a final interval of 10 days before seed is planted.

Acetic Acid and Pyroligneous Acid as Soil Disinfectants. (W. L. Doran.) It was found that either of these chemicals can be substituted for formaldehyde for soil disinfection to prevent damping-off, and at less cost than formaldehyde. A description of this work has been published in the *Journal of Agricultural Research* 44:571-578, April 1, 1932, under the title, "Acetic acid and pyroligneous acid in comparison with formaldehyde as soil disinfectants." Undistilled pyroligneous acid was more effective than the distilled.

Germination of onion seeds was not injured by pyroligneous acid 6:100, 65 gallons per acre, applied to soil in the open row at the time of seeding. This treatment did not entirely prevent onion smut, however.

A dust containing 6 per cent glacial acetic acid (in diatomaceous earth), when applied to soil at the rate of 42.5 grams per square foot, afforded less complete protection against damping-off than did acetic acid applied in water to the soil. This dust applied to soil immediately before seeding did not injure the germination of beet and tobacco seeds.

Carnation Blight (*Alternaria dianthi* S. & H.). (E. F. Guba, Waltham.) Production of the best blooms was lowest with December cuttings and highest with March cuttings when benching was done on July 20, and this was influenced by a corresponding difference in the prevalence of both Alternaria blight and Fusarium wilt. Extensive observations in carnation nurseries in 1931 indicated a correlation between greater prevalence of disease and early propagation. Heavy rains in the summer of 1931 were an important factor influencing the losses from these diseases, but benching in advance of the heavy rains in July contributed greatly to their effective control.

In a test of the control of blight in the field with fungicides, Bordeaux 4:4:50 containing one pound of calcium arsenate and one-half pint of fish oil gave the best control. A spray of nicotine sulfate, salt, and fish oil, which is used occasionally to combat red spider on carnations under glass, was not an effective treatment for blight, and a spray of zinc sulfate, lime, aluminum sulfate, and fish oil, recommended in the Middle West for controlling the bacterial spot of carnations (*Bacterium woodsii* EFS), was of no value.

With the present crop, results have been obtained which show the value of using Bordeaux in the field. Results also show that early housing is of far greater value in the control of blight, and where practiced the use of fungicides in the field would appear not to be warranted.

Strawberry Gold Leaf. (E. F. Guba, Waltham.) This trouble is genetic and non-infectious, subject to modification by the environment. Seedlings of Howard 17 develop the characteristic symptoms of chlorosis. Degeneration of chlorophyll which is associated with this disease accounts for weak growth and often death. Badly chlorotic seedlings succumb soon after the leaves appear.

Adherence to asexual propagation from the original Howard 17 clon is apparently effective in avoiding the disease.

Forcing Gladiolus with the Aid of Artificial Light. (L. H. Jones.) In an effort to determine how many nights gladiolus (Crimson Glow) should receive artificial light (from 500-watt bulbs), a succession of plots was arranged to receive artificial light for one, two, three, and so on up to, and including, fifteen weeks. The check plot received no artificial light. Owing to poor soil, the results were not wholly satisfactory, but the trend of results checked with the results of previous experiments. Flowering spikes occurred when daylight was supplemented with artificial light in growing Crimson Glow planted in early autumn. Practically no flower spikes were developed when no artificial light was supplied. The greater number of flowering spikes was found in the group of plots that received the light for more than six weeks after the first leaf appeared above ground. Some flower spikes were developed in the plots receiving light for three and four weeks, and they bloomed earlier than flowering spikes receiving more light. This early blooming is consistent with previous results which have shown that, although artificial light aids in the development of flowering spikes, it also retards the date of blooming.

Plant Containers. (L. H. Jones.) In a continuation of the investigation of the effect of type of flower pot on plant growth, there has been no indication that the degree of soil acidity was altered in its range of fluctuation by either a non-porous wall or the absence of a drainage hole. Aeration of soils in both porous and non-porous types of flower pots takes place through the surface of the soil. By means of rubber vacuum discs, it was demonstrated that air did not pass through the wall of a moist clay flower pot. Two-thirds of the evaporation of moisture from fallow soils in clay pots on a dry surface took place through the wall of the pot, indicating that there was twice as much movement of water laterally as vertically. When the clay pot was on a moist surface, a considerable proportion of the moisture lost was replaced from the moist surface, and this replacement was inversely proportional to the amount of moisture in the soil of the pot.

Root development in the clay flower pot takes place, for the most part, adjacent to the inside wall of the pot. However, in plant containers of paper, glass, and metal, the root system ramifies through the soil mass with but a very small proportion of the roots occurring next to the wall of the container. The type and amount of root distribution is more closely related to moisture conditions in the soil, and possibly to nutrient relations, than to soil aeration.

Plant containers made of paper resistant to the decomposing action of soil organisms have proved satisfactory for the germination of seeds, production of seedlings, and development of plants. Paper pots made of heavy paper that decomposed, induced a nitrogen deficiency in the soil. However, if the paper was light weight, the pot was practically destroyed before a nitrogen deficiency occurred.

To moisten properly the soil mass in clay pots which became dry, two normal waterings were necessary. For non-porous containers, one normal watering was sufficient to accomplish the same object.

Nutrient Factors in Relation to the Region of Root Distribution in Plant Containers. (H. D. Haskins and L. H. Jones.) Preliminary work has laid the foundation for an investigation concerning the relation of nutrient movement in plant containers to moisture movement as influenced by evaporation forces. Bottom watering was followed by resulting incrustations on the surface

of the soil in the non-porous pots, but not in the porous pots. In the non-porous container, the only place where evaporation can occur is at the soil surface. In the porous pots, there is a greater loss of soil moisture through the wall of the pot than from the soil surface. It thus appears that the soluble salts move in the same direction as the moisture. Chemical analysis showed that, in soils in clay pots, the disappearance of nutrients became successively slower from the region near the pot wall to the center of the soil mass. In a porous or clay pot the most extensive root development takes place near the inner surface of the pot; while in a non-porous pot the root system ramifies throughout the entire soil mass.

Diseases of Outstanding Importance in 1932. (O. C. Boyd and W. H. Davis.)

Cherry bacterial blight (believed to be due to *Bacterium cerasi* F. L. Griffin rather than *B. pruni* EFS.).

Downy mildew (*Pseudoperonospora cubensis* (Berk. and Curt.) Rostew.) of summer squash and Blue Hubbard winter squash.

Anthracnose of watermelon caused by *Colletotrichum lagenarium* (Pass.) Ell. and Hals.

Twig blight and canker of *Juniperus sp.* caused by *Phomopsis sp.*

Bacterial spot of carnation caused by *Bacterium woodsii* EFS.

Peach scab caused by *Cladosporium carpophilum* Thuem.

Pear scab caused by *Venturia pyrina* Aderh.

Fire blight of pear, apple, and quince caused by *Bacillus amylovorus* (Burr.) Trev., largely confined to yard trees and neglected orchards.

Spur blight of raspberry caused by *Mycosphaerella rubina* (Pk.) Jacz. on Herbert and other red varieties; anthracnose caused by *Plectodiscella veneta* (Speg.) Burk. on both red and black varieties; *Mycosphaerella rubi* E. W. Roark, although not unusually prevalent on foliage, caused severe girdling of bearing canes of red varieties on Cape Cod.

Gray mold rot of strawberry caused by *Botrytis cinerea* Auct.; stunt, barrenness, and early dying of strawberry plants, apparently due to the disease, "dwarf" or "crimps," caused by the nematode, *Pathoaphelenchus fragariae.*

Bacterial wilt of cucurbits caused by *Bacillus tracheiphilus* EFS.

Downy mildew of cucumbers and muskmelons.

Wilt of winter squash caused by *Mycosphaerella citrullina* (C. O. Smith) Gross.

Early blight of celery caused by *Cercospora apii* Fresen.

Bean Blights caused by *Bacterium phaseoli* EFS. and *B. medicaginis phaseolicola.*

Downy mildew of onion (*Peronospora schleideni* Ung.).

Mosaic of tobacco.

Cytospora canker of Blue and Norway spruces, caused by *Cytospora sp.*

Peony blight caused by *Botrytis paeoniae* Oud.

Hollyhock rust (*Puccinia malvacearum* C. G. Bertero).

Delphinium black spot caused by *Bacterium delphinii* (EFS.) Bryan.

Tulip blight caused by *Botrytis tulipae* (Lib.) E. F. Hopkins.

Rose black spot caused by *Diplocarpon rosae* Wolf, and powdery mildew, *Sphaerotheca pannosa* (Wallr.) Lév.

Iris rhizome soft-rot caused by *Bacillus carotovorus* L. R. Jones.

Bacterial wilt of sweet corn, caused by *Aplanobacter stewartii* (EFS.) McC.

Smut, *Ustilago zeae* (Beckm.) Ung., caused more loss to corn than all other diseases combined and appeared to be more damaging than in the average season.

Late blight of tomatoes, caused by *Phytophthora infestans* (Mont.) DeBary, which ordinarily causes very slight or no damage in Massachusetts, assumed

epidemic form in September, and destroyed not only the last pickings of the early crops but practically all of the late fields in the eastern half of the State. In addition, it ruined varying portions of the fall crop in many greenhouses in the Boston Market Garden section. The disease did not reach the Connecticut Valley crops until shortly before the fields were abandoned because of freeze injury. The only previously reported occurrence of this disease in Massachusetts was in 1905, when the damage was slight.

THE CRANBERRY STATION

(East Wareham, Massachusetts)

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Control of the cranberry root grub (*Amphicoma vulpina*). Some of the cranberry growers now have very efficient rigs for treating this pest with cyanide solution. Three-quarters of an acre a day can be treated with one of them at a cost of not over $55 an acre, with the present wage scale. However, this treatment never kills quite all of the grubs and so probably must be repeated in about ten years. Because of this and the cost of the treatment, it has seemed desirable to develop a control by flooding if possible. In this connection, the season's experience in the flooding of two badly infested bogs seems highly suggestive. On one of these bogs the full winter flood was held till July 4. This very late holding of the winter water failed to reduce the grub infestation noticeably. The winter flood was removed from the other bog on April 3, and the bog was reflooded again from May 16 to July 9, the water ranging from 6 inches to 2 feet deep over the sand surface. The temperature of the water of this reflow was taken in two widely separated locations carefully selected to represent average conditions, at depths of 6 inches and 1 foot, at 7 a. m. and 2 p. m. from May 27 to July 9, inclusive. The following table shows the range of these temperatures.

		Temperatures — °F.			
		At one-foot depth		At six-inch depth	
Months		7 a. m.	2 p.m.	7 a.m.	2 p.m.
May (5 days)	Highest	66	72	67	74
	Lowest	58	67	59	67
	Average	63	69+	62	70
June (30 days)	Highest	73	87	73	88
	Lowest	58	63	58	64
	Average	64+	74+	64+	76
July (9 days)	Highest	72	82	73	84
	Lowest	66	70	65	70
	Average	68+	77	68+	77+

So few of the grubs survived this reflow that they could hardly be found. It seems certain that the grubs were killed by the long reflow following, after a considerable period, early removal of the winter flood; but as the results of this treatment were so markedly different from those obtained by very late holding of the winter water, it should be tried further.

It was observed that the false blossom leafhopper (*Ophiola*) hatched in considerable numbers on both bogs after the late flooding operations described above.

Pyrethrum dust. (Dr. E. A. Richmond, employed locally by the Crop Protection Institute, cooperating.) The last annual report of the Cranberry Station con-

tained a brief statement of the results of tests to control certain cranberry pests with pyrethrum dust mixed with a gypsum diluent of 300-mesh fineness. All that dusting was done with hand dusters.

This year work with this dust was continued, but with a Root power duster mounted on a carriage home-made for use on cranberry bogs. In general the results of this work were highly satisfactory. The rig was drawn around on the bogs by two men, and they evidently injured the vines no more than spraying operations do.

Many tests were conducted in which different quantities of a mixture of the dust, made up of 1 part of pyrethrum and 9 parts of gypsum by weight, were applied in treating the false blossom leafhopper (*Ophiola striatula*). As little as 70 pounds to an acre gave a satisfactory kill in some cases; but because of the variation of pyrethrum in toxicity and of the difficulty of making an entirely even distribution of the dust, it was finally found that 100 pounds was about the right amount to use. Reasonably careful dusting with this amount of the mixture was commonly found to kill 99 per cent of the hoppers present. This treatment was a more effective and generally more satisfactory control for this insect than either spraying or flooding have ever been. It was also cheaper than spraying. Perhaps its most important advantage over flooding and spraying is that it may be applied without any risk when the vines are in full bloom and all the hoppers have hatched.

A dust mixture of 4 parts of pyrethrum and 6 parts of gypsum, by weight, used at the rate of 100 pounds to the acre, proved as effective as a pyrethrum soap spray for the control of the second brood of the black-headed fireworm (*Rhopobota vacciniana*) when the worms were small but rather well sewed up in the cranberry tips. This dust has not been tried against the first brood of this insect.

One part of pyrethrum to nine parts of gypsum, applied with hand dusters, was fairly effective in killing the moths of the cranberry girdler (*Crambus hortuellus*), but it is probable that a 2 to 8 mixture is advisable for this purpose.

Gypsy moth and contact sprays. The gypsy moth was very abundant this year in a large part of the Cape Cod region. As this prevalence came after several years of relative scarcity, it caught a good many of the cranberry growers napping, and bog infestations were rather generally neglected till the worms were considerably grown. This promised to develop into a serious situation, for stomach poisons are not effective on cranberry bogs against the caterpillars of this insect after their early stages, and very many bogs were without water supplies for flooding. Immediate attention was given to work with contact sprays, and it was found that the following sprays killed the worms in all stages satisfactorily when used at the rate of 400 gallons to the acre:

1.	Pyrethrum soap	7 pounds
	Water	100 gallons
2.	Nicotine sulfate	$1\frac{1}{3}$ quarts
	Soap	4 pounds
	Water	100 gallons

These sprays were most effective when applied early in the morning, for then the worms usually work in the tops of the vines where they are easily reached with a spray more than they do later in the day.

Nicotine sulfate and the cranberry fruit worm. It has become evident, as a result of spraying carried on in several seasons, that a nicotine sulfate spray at the end of the cranberry blossoming period controls the fruit worm to a considerable extent. As it has not been clear how it does this, special experiments were conducted, and it was found that the insect is affected by the spray in the three following ways:

1. Some of the moths are killed and many more are driven off of the sprayed area.

2. Most of the eggs well hit by a spray of 1 quart of nicotine sulfate in 100 gallons of water fail to hatch. This ovicidal action would be more valuable were it not so difficult to reach a high percentage of the eggs without running up the cost by applying a great amount of the spray.

3. Cranberry vines and berries treated with a spray of 1 1/3 quarts of nicotine sulfate in 100 gallons of water strongly repel the moths from laying their eggs for at least 5 days. This occurred in cages both in the laboratory and on a bog, the moths having been introduced some time after the treatment was applied and living in most cases till well toward the end of the test.

Control of the cranberry spittle insect. The general experience of cranberry growers and the results of the season's study indicate that it requires 1 1/3 quarts of nicotine sulfate and 4 pounds of soap in 100 gallons of water applied at the rate of 400 gallons to the acre to control this pest where water for flooding is not available. Pyrethrum sprays and dust fail to check it properly.

Weather Observations. (H. J. Franklin.) Daily local weather observations were made and reported to the office of the Weather Bureau at Boston. Further records bearing on frost forecasting were made for the station by observers at North Harwich, East Gloucester, Carlisle, Fitchburg, Worcester, and Holliston.

Cranberry Varieties. (H. J. Franklin.) The study of varieties was continued during the early months of 1932. A comparative study of their characters in detail, as related to their places of origin, revealed the fact that the native cranberry floras of New Jersey, the Massachusetts mainland, and outer Cape Cod have had significant separate evolutions.

Bog Irrigation. (H. J. Franklin.) On July 20, 1932, during a drought, a square area of bog surface of 100 square feet was wet with 150 gallons of water (about 65,250 gallons per acre), and on this plot two thermometers were placed a few feet apart with their bulbs at the same height as the cranberry flowers and young fruit (about 4½ inches above the bog surface.) For comparison two other thermometers were similarly placed on the bog about 30 feet outside the watered plot. All the thermometers were occasionally shifted in location to get as accurate averages of the relative temperatures as possible. The results were as follows:

Date	Weather Conditions	Hour	Average Temperature °F.		Difference between watered and unwatered °F.
			Watered plot	Unwatered Check	
July 20	Clear, slight breeze	2 p. m.	98.75	100.25	1.5
July 21	Clear, slight breeze	2 p. m.	97.50	99.75	2.25
July 22	Clear, strong breeze	12:30 p. m.	96.62	100.50	3.88
July 22	Clear, slight breeze	1:30 p. m.	95.87	98.92	3.05
July 23	Cloudy	2 p. m.	76.25	77.	.75

On July 23 a second plot, like the one watered on July 20, was wet with 150 gallons of water, and 25 gallons more were added on July 25 at 7 a. m. Two thermometers were placed on this plot also. The following table records the average temperatures on the two watered plots and the unwatered check.

Date	Weather Conditions	Hour	Average Temperature °F: Plot watered July 20	Plot Watered July 23	Unwatered check	Average difference between watered and unwatered °F
July 25	Clear, strong breeze	2 p. m.	92.25	92.38	96.91	4.59
July 26	Clear, strong breeze	12:30 p. m.	89.25	88.43	92.1	3.26

The general average difference in temperature between the watered and unwatered plots for five days (excluding one cloudy day when practically no difference occurred) was 3.08° F. Readings taken at different times of day indicated, as would be expected, that the greatest difference occurred in the early afternoon, i. e., during the warmest part of the day. It is interesting to note that even six days after water was applied to the first plot, the difference in temperature, in comparison with the unwatered bog, was as great as during the first day after application.

During the period when the berries were setting, considerable injury to the crop occurred on many bogs, for many flowers turned brown and dry and, of course, did not set fruit. Drought conditions caused most bogs to be unusually dry during the blooming season. The critical temperature above which cranberry flowers are injured is not known; but in view of the effect which watering has on the air temperature above and near the surface of a bog, as shown by the experiments just outlined, it seems probable that had the bogs been as moist as in normal seasons, the temperature might in many cases have remained below the point where injury occurs. How much this reduction of temperature is due to transpiration from the cranberry plants and how much to direct evaporation from the bog, it is impossible to say. Both these factors, however, depend more or less on the supply of moisture in the surface soil of the bog.

Cranberry Pollen Studies. (W. H. Sawyer.) Through a detailed study of the cranberry flower and pollination, several interesting facts have been developed.

Even during hot, dry weather, if pollination does not occur, the stigma remains moist and receptive for pollen for seven days, and under more favorable conditions of coolness and moisture, it is evident that pollination can take place for a considerably longer period. This is very significant on its influence in insuring a set. Also pollen must be thoroughly ripe before it is capable of germination, and such pollen is found only in anthers that have begun to shrink and turn brown.

When pollen is ripe it is shed from the anthers upon the slightest disturbance. A little pollen may be shed when the flower first opens, but maximum liberation takes place a few hours before the style has elongated enough to bring the stigma even with the anther tips. This occurs from twenty-four to thirty-six hours after the flower has opened.

The shape of the flower and the arrangement of the stigma and anthers are such as to supply reasonable justification for a lack of self-pollination. Distilled water was found to be as satisfactory as any other medium tried for the germination of cranberry pollen, but the pollen tubes did not grow very satisfactorily after germination. A 1 per cent solution of cane sugar was found to be the best medium for all purposes, and the best results were obtained when the pollen floated on the surface of the solution.

The range of temperature for pollen germination under laboratory conditions was 29° C.; with a minimum of 8°, the optimum from 28° to 32°, and a maximum of 37°. Within the temperature range where germination was possible, the percentage of germination remained constant, but there were variations in the time required, and these differences were also influenced by the variety.

It is evident from yield records of several varieties that there is a correlation between a high percentage of pollen germination and high yield, in spite of the fact that it would seem reasonable to assume that even the varieties with poor-germinating pollen would disseminate sufficient pollen to meet all "set" requirements.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Frozen Fruits and Their Utilization in Frozen Dairy Products. (M. J. Mack and C. R. Fellers, Horticultural Manufactures.) This cooperative project has been active for three years. A full report of the investigation has been published in Bulletin 287.

The Vitamin C Content of Strawberry Ice Cream Containing "Frozen Pack" Fruit. (C. R. Fellers, Horticultural Manufactures, and M. J. Mack.) This study was planned to determine the Vitamin C potency of fresh strawberries, frozen packed strawberries, and strawberry ice cream. It was conceivable that Vitamin C might be partially destroyed either in the process of freezing, during storage, or in the rigorous beating of ice cream in the ice cream freezer. However, the data collected by feeding tests on guinea pigs indicate no destruction of Vitamin C either in the frozen storage of strawberries or in the preparation and storage of strawberry ice cream containing the frozen pack fruit. Thus strawberry ice cream may be considered a source of Vitamin C.

A Study of Ice Creams High in Fat Content. (M. J. Mack.) More data have been accumulated on this subject during the past year. Ice creams varying in fat content from 20 to 30 per cent are now being made by many New England manufacturers. Such ice creams vary markedly in character from the usual commercial product in which the fat content invariably lies between 10 and 20 per cent.

The most serious problem which is encountered in the making of high-fat ice creams is to control the viscosity of the mix. An excessive viscosity usually results which interferes with certain processes in making the mix, as well as with freezing and packaging of the product. Some sources of fat prove to be much more satisfactory than others in the control of viscosity. The findings thus far would indicate that, in the making of ice creams high in fat content, the percentage of non-fatty ingredients, as well as processing and freezing procedures, must all be altered wherever possible to bring about lower viscosity of the mix.

The Effect of High Initial Aging Temperatures on Certain Physico-Chemical Properties of Gelatin Dispersions. (W. S. Mueller.) The purpose of this investigation was to determine what effects various high initial aging temperatures have, when used for definite periods of time, on the basic viscosity and gel strength of gelatin dispersions. A gelatin-ice cream mixture, pure gelatin-water solution, and other gelatin dispersions such as cane sugar, butter oil, and plasma solids, were used. This study has been completed and a paper prepared for publication.

The following conclusions have been made:

1. When using a gelatin-ice cream mixture —

(1) Initially aging an ice cream mix for 1 to 6 hours at temperature range of 10° to 30° C. (50° to 86° F.), followed by a low aging temperature, increased the basic viscosity and gel strength over those mixes aged at the low temperature, 2.2°C. (36°F.) only.

(2) As the initial aging temperature is raised from 10°C. (50°F.), this increase in basic viscosity and gel strength reaches a maximum at 20°C. (68°F.), then decreases with further increase of the initial aging temperature.

(3) Initially aging an ice cream mix at or near the transition temperature of gelatin, 38.03°C. (100.5° F.), has no marked effect on basic viscosity and gel strength.

(4) Initially aging an ice cream mix at temperatures above the transition point of gelatin decreases the basic viscosity and gel strength when compared to mixes aged at the low temperature 2.2°C. (36°F.) only.

(5) The magnitude of the basic viscosity and gel strength changes increases with an increase in the initial aging temperature period. However, the first two hours produce the greatest change.

2. The effect of high initial aging temperatures on pure gelatin-water solution was similar to that on gelatin incorporated in an ice cream mix.

3. Sugar, plasma solids and butter oil had a marked influence on the magnitude of the basic viscosity increase due to the use of a high initial aging temperature, 20°C. (68°F.).

4. The observed effects of various initial aging temperatures on the basic viscosity and gel strength of gelatin systems indicate that the colloidal behavior of gelatin is affected by factors which are not generally recognized by current theories.

5. The observed increase in basic viscosity and gel strength, due to the use of a high initial aging temperature, points the way to a more economical use of gelatin in ice cream.

The Feasibility of High Aging Temperatures in the Manufacture of Ice Cream. (W. S. Mueller and J. H. Frandsen.) The object of this study was to determine the feasibility of using an aging temperature of 68° F. A four-hour high aging temperature period was selected as standard procedure. The 68° F. aging temperature was used alone and also followed by a low aging temperature. Each mix aged at 68° F. was compared to a portion of the same mix which was aged at 38° F. and served as the control. Comparisons were made on the following factors:

1. Bacterial growth.
2. Titratable acidity.
3. Hydrogen-ion concentration.
4. Basic viscosity.
5. Whipping ability.
6. Body and texture.
7. Melting resistance.
8. Melting appearance.

This study was completed during the past year and is now being prepared for publication.

The following conclusions were drawn:

(1) When an ice cream mix containing gelatin was aged at 68° F. for a period of 4 hours, either alone or followed by a low aging period, the efficiency of the gelatin was increased.

(2) This increased gelatin efficiency was shown by the improvement in body and texture, increase in melting resistance, and slight retardation in rate of whipping when compared to an identical mix aged at 38° F.

(3) When an ice cream mix containing 14 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.4 per cent gelatin (175 Bloom) was aged at 68° F. for 4 hours, the efficiency of the gelatin was increased to such an extent that the gelatin content could be reduced 0.1 per cent without any loss in the quality of the finished product.

(4) Aging a pasteurized ice cream mix up to 6 hours at 68° F. had no effect on bacterial growth, pH, and titratable acidity which would be of any commercial significance.

(5) When an ice cream mix containing gelatin was aged at 68°F. for 4 hours, the basic viscosity was slightly decreased, but the basic viscosity was greatly increased when the high temperature aging period was followed by a low temperature aging period, as compared with a mix aged only at 38° F.

(6) When an ice cream mix containing no gelatin or other stabilizer was aged at 68° F. for 4 hours, there was no marked effect on the consistency and whipping ability of the mix or on the melting resistance, body, and texture of the finished product.

(7) When an ice cream mix containing the optimum amount of gelatin for low temperature aging was aged at 68° F. for 4 hours, there was an excessive retardation in melting and a curdled appearance on melting. This objectionable melting behavior can be corrected by a reduction in gelatin without lowering the quality of the finished product.

(8) It is conceivable that in ice cream plants where the cooling of mixes is not being carefully checked, mixes may be aged unintentionally for several hours at a temperature above 50° F. This unintentional high aging temperature in all probability is a big factor in causing the curdled appearance on melting which has troubled some ice cream manufacturers but could not be explained.

The Theoretical Causes of the Factors Involved in the High Initial Aging Temperature Phenomena. (W. S. Mueller.) In order to find an explanation for the structural changes in a gelatin gel, as a result of high aging temperatures, a detailed study of the optical rotation of pure 1 per cent gelatin-water solution was made. Gelatin-water solutions were aged at various temperatures (50°-122° F.) for a period of four hours and then at 36° F. for a period of 44 hours. The control solution was aged at 36° F. only, for a total period of 48 hours. The optical rotation was determined after a total aging period of 24 hours and 48 hours. The results so far obtained show that high initial aging temperatures have no marked effect on the optical rotation after a total aging period of 24 and 48 hours when compared to an identical solution aged at 36° F. only.

The following temperatures were used when studying the changes in optical rotation with time, until optical equilibrium had been obtained: 34.7°, 50°, 68°, 86°, 104°, and 140° F.

The effect of high aging temperatures on the Tyndall phenomenon of pure gelatin-water solutions is now being studied. It is hoped that these data, in conjunction with the optical rotation data, will bring to light a satisfactory explanation for the structural changes in a gelatin gel, due to the use of a high (68° F.) initial aging temperature.

A Study of the Changes that Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) Work has progressed on the preparation of cream for freezing, but no methods thus far have proved satisfactory in studying the changes that occur in the frozen cream.

The Comparative Efficiency of Electrically-operated Tanks versus Ice in the Cooling of Milk. (J. H. Frandsen.) A study of the efficiency of various methods of cooling milk, as practiced under actual farm conditions, is now in progress. The efficiency of most recent electric cooling units is also being studied.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials Which Promise Value in Insect Control. (A. I. Bourne.) Weather conditions in the early spring of 1932 were favorable for application of oil sprays. There was very little interruption due to inclement weather. Moderately high temperatures prevailed at the time the buds were breaking, and no sudden drops in temperature were encountered sufficient to cause a breakdown of the sprays and consequent injury to the trees from the free oil liberated. No evidence of burn was noted following any of the oils tested.

Four oil emulsions and two miscible oils were used in the tests against European red mite. At the dilution of 4 gallons per 100, Kleenup gave 95 per cent control; Free Mulsion, 94 per cent; and Emulso, 92 per cent. Used at the rate of 5 gallons per 100, Kleenup showed 98 to 99 per cent control; Free Mulsion, 98 per cent; and Emulso, 95+ per cent. Peninsula Oil Emulsion, a new product on the market, at the strength of 4½ gallons to 100 gave 95 per cent control. The miscible oils, Dendrol and Sunoco, maintained their usual high degree of effectiveness, both showing 98+ per cent control at the standard dilution recommended by their manufacturers.

The present tendency in the use of oil sprays appears to be toward a comparatively few of the standard, well-established types which have been in use long enough to demonstrate their safety and effectiveness under Massachusetts conditions.

Preliminary tests with various insecticides for the control of the Mexican bean beetle indicated that magnesium arsenate, either as a spray or dust, is at present the safest and most dependable material on the market. Both lead arsenate and calcium arsenate caused severe burning, in most cases killing the plants. There is, however, some evidence to show that they might be used, if necessary, during the early season when both temperature and humidity are comparatively low. Barium fluosilicate caused a slight amount of foliage burn during midsummer. However, it showed possibilities for use on late string beans when arsenicals would be objectionable because of residue on the harvested crop. Some of the commercial products containing arsenicals combined with a fungicide proved effective against the insects and safe to the foliage of the beans. They are, however, somewhat expensive, especially if used on large plantings.

In cooperation with the Pomology Department, further studies were made of different "wettable sulfurs" designed to replace lime-sulfur in the midsummer sprays. The object of these tests was to find a spray that would prove effective against scab and compatible with lead arsenate, and at the same time would avoid the foliage burn and russeting of fruit which almost inevitably follows the use of lead arsenate and lime-sulfur in the post-blossom sprays.

Mulsoid sulfur, Dritomic sulfur and a combination of flotation sulfur and finely divided sulfur were used in combination with lead arsenate. The schedule followed called for a pre-pink, a pink, a calyx, a special curculio and a cover spray and two July applications for railroad worm. The standard lime-sulfur — lead arsenate combination was used on one block, as a basis for comparison. These wettable

sulfurs were used in all sprays after the special curculio spray. In the sprays up to the calyx spray, lime-sulfur was used as the fungicide.

Tests were continued with Kolofog and flotation sulfur, both of which showed great promise in 1931. Flotation sulfur was available for the first time in a dry powder form. This was much more convenient to handle than the paste form and proved fully as effective. It marked a distinct advance in the manufacture of this product. Kolofog and flotation sulfur (paste and dry) were used throughout the season in one-half of the block in which they were tested. The remainder of the trees received lime-sulfur up to and including the calyx spray and the new materials for the remaining sprays.

While the season was not particularly favorable for spray burn or the development of scab, considerable foliage injury followed the use of lime-sulfur, and unsprayed checks showed sufficient scab to infect nearly 60 per cent of the harvested fruit. No foliage injury or damage to fruit resulted from the use of any of the wettable sulfurs.

The value of these materials in controlling disease and insect pests is shown in the following table, based on examination of the McIntosh crop at harvest.

Treatment	Percentage of Clean Fruit	Percentage of Fruit Showing Injury From:		
		Curculio	Codling Moth	Scab
Lime-sulfur Lead arsenate	85	3	9	1
Lime-sulfur Lead arsenate Lime	95	1	2	0.5
Mulsoid sulfur Lead arsenate	88	5	4	0.8
Flotation sulfur 300-mesh sulfur Lead arsenate	91	2	5	1
Dritomic sulfur Lead arsenate	92	2	4	1
Flotation sulfur (dry) (entire season)	86	1+	3	6
Flotation sulfur (dry) after Lime-sulfur	96	0	2	1+
Flotation sulfur (paste) (entire season)	80	0.2	2	18
Flotation sulfur (paste) after Lime-sulfur	93	0 3	1	5
Kolofog (entire season)	89	0.5	3	6
Kolofog after Lime-sulfur	94	0.2	1-	4
Check	23	27	19	58

In these tests the lime-sulfur—lead arsenate combination gave equally good control of scab when hydrated lime was added, and the lime reduced the amount

of spray injury to fruit and foliage. Combined sprays of lead arsenate with Mulsoid sulfur, with Dritomic sulfur, and with the combination of flotation and finely-divided sulfurs held scab to 1 per cent injury or less and also controlled insect pests very satisfactorily.

The dry form of flotation sulfur proved as effective against scab as the paste and required much less time in the preparation of the spray. Kolofog again gave very satisfactory control of scab. Samples of fruit sprayed with these materials showed excellent quality and finish. The use of lime-sulfur as a fungicide in the early sprays followed by Kolofog or flotation sulfur in the midsummer applications gave a higher control of scab than that secured by a complete season's schedule of either of these materials. Spray injury was also avoided, and such a program would allow a material reduction in cost to the grower.

Control of Onion Thrips (A. I. Bourne.) Warm weather and a slight deficiency in rainfall during the early growing season offered favorable conditions for the development of thrips, and the very general practice of planting sets close to seed onions practically insured an early and heavy infestation on seed onions. By late June the number of thrips on seed onions was unusually high and some evidence of injury was appearing. Weather conditions during July sufficiently arrested the development of the infestation so that no serious damage resulted except in some fields adjoining set onions.

The insect was somewhat slower than usual in its seasonal development and reached the peak of abundance about a week later than normal. During early August there was a sharp drop in numbers of thrips per plant, from an average of 75 per plant on August 1 to less than 10 per plant on the 15th, and a gradual decrease until harvest.

It was discovered that this sharp decline in abundance of thrips was coincident with the appearance and spread of a parasitic fungus attacking the insects and the presence of an unusually large number of predacious insects. Examination of onion fields throughout the Connecticut Valley region showed that the fungus was generally present and that its development coincided with a rapid decrease in numbers of thrips. It could not be definitely proved that the presence of large numbers of predacious lady beetles was associated with the spread of this fungus. Coccinellids have, however, been reported to feed on spores of certain of the lower Cryptograms and their presence in abnormal numbers very generally throughout onion fields in the Valley offers a possible explanation of the general distribution and rapid spread of the fungus.

Throughout the growing season observations were made of different strains of onions, in connection with the work of the Agronomy Department on onion varieties, and a marked difference in reaction of various strains to thrips attack was noted. While no strain was found to be immune, certain types were scarcely affected by the feeding of thrips, which caused other types to curl badly and practically terminated their growth.

Comparative tests of nicotine sulfate, Derrisol, and a compound of rotenone in dust form indicated that nicotine sulfate sprays gave the greatest reduction in number of thrips, and their action was more rapid that that of other products. The derris compound was somewhat slower in its initial action than nicotine but appeared to exert considerable residual effect, which retarded reinfestation except that caused by migration of thrips from adjoining fields. The rotenone compound proved least effective of the materials tested, probably due to the fact it was in the form of dust which, with present machinery for application, does not penetrate the tight axils of the leaves as satisfactorily as a spray.

The Spray Residue Problem. (A. I. Bourne.) The dry weather that prevailed during the past summer again force l the problem of spray residue upon the attention of the fruit growers. The rainfall during June was nearly 1 inch less than the normal, and more than half of the precipitation for the month occurred in one storm. There was a deficiency of half an inch in July an l of more than 1½ inches in August. While the rainfall in September was slightly greater than the normal, almost 60 per cent of this amount occurred in two storms late in the month when the McIntosh crop had been harvested. During October there was slightly more rain than normal. The fact that the greater part of the deficiency in rainfall occurred during the spraying season and extended up to time of harvest made the problem acute for early varieties and McIntosh. The precipitation in late September and October very largely removed the danger in the case of late varieties such as Baldwin. This deficiency in rainfall in itself was sufficient to make readjustment of the spray schedules necessary, but its effects were reflected also in the seasonal development of several important pests, notably railroad worm, which made proper timing of late sprays very difficult.

In many cases growers failed to apply the late sprays necessary for maggot control. Others made these applications only on late varieties. In both cases failure to control maggot resulted.

Growers who sprayed in late July or early August encountered the problem of residue on McIntosh in excess of the tolerance or dangerously near it. Growers who dusted in late summer again proved that this offers one of the most satisfactory solutions of the problem under Massachusetts conditions at present.

In preliminary tests a non-arsenical stomach poison showed to good advantage as compared with lead arsenate. This indicates a possible way out of the difficulty without forcing the growers to the practice of washing their fruit.

Systematic Study of Oil Sprays. (A. I. Bourne in cooperation with the Department of Chemistry.) The five samples tested this season were all prepared with the same emulsifying agents. The oils ranged from a spindle oil to a medium turbine oil and varied in their viscosity from 203 seconds to 619 seconds at 70° F. One sample was an asphalt base oil; the others were of the paraffin base type. These were applied as delayed dormant sprays in the college orchard, to test their comparative efficiency against overwintering eggs of European red mite and their toxicity to the trees. All the samples went into the spray solution without difficulty. They showed no tendency to break, even when dissolved in very cold water. Their efficiency as insecticides is noted in the following table.

Sample	Percentage of clusters free from mites	Number of mites per 100 leaf clusters
A3	55	70
B3	65	100
C3	60	87
D3	66	67
E3	66	73

All the samples gave practically perfect control. The differences above are too small to be of significance when compared with unsprayed trees which showed an infestation of more than 500 mites on single clusters and averaged more than 18,000 mites per 100 clusters. No injury to buds by burning of tissues or retarding of growth was noted.

Apple Maggot Control. (A. I. Bourne.) Apple maggot was more abundant throughout the entire State this past season and caused more damage than

has been reported in any year of its present period of abundance. The peak of emergence of flies was later than normal, and the flies were active in the orchards over a much longer period than usual. This was largely associated with the very light rainfall during late spring and early summer which left the soil dried and hard packed, a condition very unfavorable for the emergence of the flies. Under such circumstances proper timing of the sprays was difficult.

In the demonstration orchards where the growers were devoting especial attention to maggot control and carried out a complete control program, the pest was held to an average of less than 1 per cent damage. In the 14 blocks from which records were taken, 4 showed no fruit injured by maggot, and in 4 others the number of injured apples was 3 or less. In 7 of the blocks the fruit scored 85 per cent clean or higher, and in every case maggot injury was held to a lower figure than that of any other major pest.

One of the outstanding features of the season's work was the influence of orchard environment or, in other words, the necessity of proper treatment of neglected trees or orchards surrounding commercial blocks. Many growers found that even with the most thorough program possible they could not control maggot in their orchards because of the exposure of their blocks, on one side or more, to neglected apple trees.

The experience of the past season demonstrated that growers in whose orchards apple maggot is a problem must take suitable precautions to clean up their orchard surroundings, since the influence of orchard environment is in most cases the limiting factor determining satisfactory control of the insect or complete failure.

Introduction of Parasites of Oriental Fruit Moth. (A. I. Bourne.) During the last two years the Department of Entomology has cooperated with the U. S. Bureau of Entomology in the introduction and establishment of parasites of the Oriental fruit moth. Colonies of *Macrocentrus ancylivorus* were liberated in peach orchards throughout Hampden County where the infestation of fruit moth was sufficient to allow the establishment of the parasites.

Recoveries from twig collections indicated that the parasites were able to survive the winter of 1931-32 in Hampden County and build up a considerable population in the peach orchards the following spring. In orchards where liberations were made in 1931, a considerable reduction was noted in early twig injury the following spring, and growers reported beneficial results on the basis of the crop at harvest.

If a sufficient supply of parasites can be obtained, more extensive liberations will be made another season in other peach-growing sections of the State into which the fruit moth has now spread.

Plum Curculio. (W. D. Whitcomb.) Studies of the plum curculio under controlled temperatures maintained at 55°, 65°, 75°, and 85° F. were continued with special attention to influence of temperature on oviposition. The activity of ten pairs of mated beetles at each temperature was recorded daily.

The number of eggs laid increased at each higher temperature in an approximate ratio of 1:5:9:12, and about 75 per cent of the eggs were laid during the first 20 days of oviposition regardless of the temperature. Slightly more eggs were laid in the first 10 days than later but the ratio of egg punctures to feeding punctures was about 4 per cent greater in the second 10-day period. At each temperature the last eggs were laid about 55 days after oviposition began. The average number of eggs per female per day laid during the first 20 days was 0.72 at 55°, 3.44 at 65°, and 10.21 at 85° F. The maximum number of eggs laid during life by one female

beetle was 41 at 55°, 169 at 65°, 240 at 75°, and 332 at 85° F., while the greatest oviposition in one day was 22 at 85° F.

Development of the immature stages was not completed at 55° and was very slow at 65° F. At 75° all development increased rapidly, and a slight additional stimulation occurred at 85° F.

When the beetles had only poisoned apples for food, the average number of days which they lived decreased with each increase in temperature and with each increase in concentration of lead arsenate from 3 pounds in 100 gallons to 4, to 5, to 6 pounds. The number of days in which the poison killed the beetles was quite consistent at the two higher temperatures, but at 55° and 65° F. the time was much more variable among individuals. The activity of the beetles was inconsistent when feeding on fruit sprayed with the lowest concentration of lead arsenate, but at the higher concentrations the average number of punctures per beetle before death decreased from 4.5 on 4 pounds to 3.3 on 5 pounds to 2.3 on 6 pounds of lead arsenate per 100 gallons of water with no consistent variation in respect to temperature. With one exception the average number of eggs per beetle was less than two in all fruit sprayed with lead arsenate at the rate of 4 pounds or more per 100 gallons. In the majority of the experiments no eggs were laid in sprayed fruit more than two days after the first activity took place.

The comparative effectiveness of spray and dust for the control of the plum curculio in apples was studied on Gravenstein at Westford. Applications were made by the grower at the recommended time. Examination of 43,568 apples showed 6.45 per cent of the dusted apples with curculio punctures and 2.80 per cent of the sprayed apples. A similar percentage in favor of the spray treatment was apparent in both the dropped fruit and harvested fruit.

Naphthalene as a Fumigant for the Control of Greenhouse Insect Pests. (W. D. Whitcomb.) Experimental fumigations with vaporized naphthalene in a tight chamber at the rate of 1½ ounces in 1,000 cubic feet resulted in practically perfect control of red spider nymphs and adults from one fumigation of six hours at 80° F. with relative humidities of 90, 80, 70, and 60 per cent. Two and three fumigations at 75° F. gave perfect control at each relative humidity. However, one fumigation at this temperature gave perfect control only at 90 per cent humidity, and the mortality decreased with each decrease in relative humidity from 80 to 60 per cent.

When the dosage was diminished to 1 ounce in 1,000 cubic feet the control was consistently satisfactory only after three fumigations, especially at 60 per cent relative humidity. The natural mortality of the red spider on these plants averaged 13.5 per cent.

The mortality of red spiders when exposed without napthalene for six hours to the humidities used in fumigating increased with each increase in relative humidity and with each additional exposure. Two exposures of six hours at 80° F. and 90 per cent relative humidity killed over 50 per cent of the red spiders without napthalene.

Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb.) The potential infestation by the carrot rust fly in 1932 was 8.07 pupae per square foot where carrots were left in the ground over winter and was almost identical with a similar count (8.16) in 1931. However, the abnormally dry weather during June and July practically eliminated economic injury and prevented the building up of a normal second generation infestation. This condition was at least partially explained when none of the eggs confined at a constant temperature of 85° F. hatched while 85 to 90 per cent of them hatched between 55° and 75° F. No

flies emerged from overwintered pupae confined at 85° and only 44 per cent emerged at 75° F. The average date of emergence was 15 days later at 55° than at 75° F. Adults lived longest at 55°, and the largest number of eggs was laid at 75°, but 65° appeared to be the most favorable temperature for normal development.

In the field plantings there was no first generation injury in the untreated check and only one in 2050 carrots examined showed severe injury. The normal field infestation by the second generation was about 10 per cent most of which was slight and moderate, rather than severe. Celeriac was free from injury in comparison to other years when this plant suffered moderate to severe damage. Among new varieties of carrots which were observed for susceptibility, Table Gem and Tendersweet showed a tendency toward injury in spite of the light infestation. Under the existing conditions, broadcasted applications of tobacco dust and soot were very satisfactory when applied three times at weekly intervals, although the plots receiving two applications of these materials showed about the same infestation as the untreated check.

Influence of Temperature on Development of Red Spider. (W. D. Whitcomb.) The abundance of the red spider on greenhouse plants increased with the temperature, and on cool-growing plants such as carnation, injury by this pest can be reduced to a minimum by maintaining temperatures near 50° F. during cool weather. In experiments at 50° F. development of the younger stages was not complete, although some eggs were exposed for 57 days before it was determined that they would not hatch. The average number of days required for development from the newly laid egg to the adult was 29.1 at 60°, 12.4 at 70°, and 7.0 at 80° F. Eggs were hatched in 11.72, 5.35, and 3.53 days at the higher temperatures respectively, and over 90 per cent of the eggs hatched at these temperatures.

Although red spider eggs do not hatch at 50° F., there is a slight biologic development at this temperature which causes hatching in less than the normal period when the eggs are transferred to more favorable temperature. This biologic development varies directly with the length of exposure at 50° F.

DEPARTMENT OF FARM MANAGEMENT

J. A. Foord in Charge

Enterprise Relationships and Farm Organization on Selected Dairy Farms in Massachusetts. (R. L. Mighell.) Studies of the effect of replanning the labor program and the internal organization of enterprises on dairy farms have been continued. It has been discovered that significant savings in labor can be made in many farm tasks, for example daily chores, by means of careful planning. Frequently an inexpensive piece of equipment, or slight change in routine, will result in a considerable reduction of labor time. For example, on one farm the installation of an 18-foot extension of pipe line made a net saving in chore time of 13.4 minutes daily or more than 1½ hours per week.

Types of Farming in Vegetable Garden Areas. (R. L. Mighell, J. E. Thigpen. Cooperative with the Extension Service.) Records secured in the 1930 season have been further analyzed, and the amounts and distribution of labor used on different vegetable crops presented in tabular and graphic form for use in giving a more accurate picture of the types of farming in vegetable areas and in planning more profitable crop combinations. Variations in amounts of labor used for the same operations have furnished the starting point for the study of labor-saving methods and technique.

The Cost of Silage Production in Massachusetts with Special Reference to the Use of Machinery. (C. I. Gunness, J. A. Foord, and J. E. Thigpen. Cooperative with the Bureau of Agricultural Engineering, U.S.D.A., and the Departments of Farm Management and Agricultural Engineering of the Experiment Station.) The analysis of the data from a field study of silage-production methods made in October and November, 1931, shows definite relationship between man-labor inputs and acreage of silage corn, stoniness of the soil, and types of machinery used. The difference in amounts of labor required with and without certain machines can be used as measures of probable labor savings, assuming that other causes of variation in labor are averaged out.

Other basic data resulting from the study are farmers' estimates of annual repairs and probable life of different machines. These data are used in estimating average annual costs of such machinery. The annual costs can then be balanced against the estimated value of labor savings in case the purchase of a new machine is under consideration.

Economical Silage Production on Dairy Farms -- Labor and Machinery Costs. (R. L. Mighell and R. H. Barrett.) This study developed from the preceding one, as one of the most practical and at the same time most inexpensive pieces of labor-saving equipment in silo filling was found to be the low-rack wagon. Only four farms among the 64 studied used such wagons, but their average time for filling silo was only 1.6 hours per ton as contrasted with an average of 2.0 hours per ton for all the farms.

To test these results experimentally, an inexpensive low-rack wagon was built in the college engineering shop in September 1932, with a discarded automobile rear end for the rear wheels and axle and front running gear from an ordinary farm wagon. This wagon was tested under actual silo-filling conditions on the college farm and on four farms near Amherst. On three farms complete time records were taken on all operations. As a typical instance the time required to load silage corn on the low wagon was 23.6 man minutes per ton in comparison with 35.1 man minutes per ton with a wagon 41 inches high. (Average of 16 loads apiece). The low wagon is 22 inches high as compared with 38 inches to 50 inches for wagons in common use. With a low wagon, the corn can all be loaded from the ground without the necessity for anyone on the load. Recent studies in New Hampshire and Connecticut on this type of wagon are in line with these results.

Labor-Saving Methods and Technique on Vegetable Farms. (R. L. Mighell, R. H. Barrett.) This study is one of the first attempts to apply time and motion study methods to the operations on vegetable farms. Analyses of the motion pictures and time records secured in the 1931 season were continued this year, and further field study was directed particularly to asparagus, beets and carrots. As a result of the study of harvesting and packing operations on bunch beets and carrots a new and improved technique has been developed for these tasks. Typical tests of the new method of bunching and tying show that the time has been reduced from 5.3 man minutes per box with a common method now in use to 2.9 minutes per box with the new method.

With asparagus a new system of sorting and packing is being developed from ideas originally thought out by one grower. Preliminary tests indicate that the new system as adapted to fit different conditions will effect a reduction of one-fourth to one-third in the man labor needed on this job. Many minor changes such as rearranging labor crews, subdividing the work differently, providing convenient sorting tables and more desirable field boxes and so on, have been suggested

to growers in the field and tested out with success. Motion pictures have been very helpful in studying detailed operations in certain tasks and also furnish an effective means of presenting results to growers.

Live Stock Management, Methods and Costs. (J. A. Foord.) The positive reactors to the blood test for Bangs disease from the college herd have been kept in loose pens for three years, being "tied up" only for milking and grain feeding. The method has shown advantages in reduced hours of labor and amount of equipment needed, although with somewhat higher costs for bedding. Production has been well maintained, and clean milk of low bacterial count produced. Very little more floor space is needed than in the better type of stable. The method is worthy of consideration by practical dairymen.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, G. J. Larsinos, J. W. Kuzmeski, F. A. McLaughlin, J. T. Howard.) During the fiscal year, 1,607 samples of feeding stuffs were officially collected and examined in the control laboratories. The results show that at least 97 per cent of the samples collected varied less than 1 per cent from stated guarantees in protein, fat and fiber content. The gross receipts from the registration of feeding stuffs in 1932 (calendar year) were $21,200, derived from 1,060 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, Margaret E. Nagle.) From October 1, 1931, to October 1, 1932, the seed laboratory analyzed 1516 seed samples, 463 of which were collected by the State Department of Agriculture, 304 sent in by dealers and farmers and 194 by the Rhode Island Department of Agriculture, 354 purchased from wholesalers for special tests. The remaining 201 were accounted for in tests of ingredients of grass seed mixtures, some mixtures containing as many as eight ingredients.

	Massachusetts Official	Massachusetts Non-official	Rhode Island	Total
Purity only	41	26	53	120
Artificial germinations	257	572	3	832
Field germinations	0	(239*)	0	...
Purity and Germination	366	60	138	564
	664	658	194	1516
Field crops	32	61	18	111
Forage crops	375	140	173	688
Vegetables	257	446	3	706
Flower seeds	0	2	0	2
Tree seeds	0	9	0	9
	664	658	194	1516

*239 field tests are duplications of laboratory tests; portions of same samples used.

Field tests to determine trueness to type were again conducted in cooperation with the Department of Agronomy which tested 11 samples of alfalfa, 23 samples of red clover, and 3 samples of sweet clover; and the Department of Olericulture which tested 239 samples of sweet corn and 115 samples of peas.

Dairy Law. (P. H. Smith, J. T. Howard, J. A. Martell, H. L. Allen.) During the year ending December 1, 1932, 7,603 pieces of Babcock glassware were tested. Condemned glassware consisted of four milk-test bottles. One hundred and six certificates of proficiency were awarded.

One hundred and ninety-one creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, one machine was condemned, and repairs were ordered on twenty-five. Six plants were re-inspected to approve repairs. Special investigations were made at twelve plants.

Advanced Registry Testing. (P. H. Smith.) Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 483 cows located on 61 different farms. This does not include the herd tests where all animals in each herd are placed on test. Of these there are fourteen, five of which are supervised by men sent out from this office and nine by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1932

Materials sent in:	
Milk and cream, butterfat only	362
Milk, solids and fat	29
Feeds	108
For other departments of Experiment Station and College:	
Milk, for butterfat	237
Milk, for solids	7
Dry matter, forage crops	3,196
Complete fodder analyses	169
Dry matter and nitrogen	116

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Records for the year show that 106 firms have registered for sale in the State 537 brands of mixed fertilizer and fertilizing materials and 36 brands of agricultural lime and gypsum. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

During ten weeks following April 1, four men employed to draw samples for inspection purposes sampled 23,827 sacks or containers, representing 8,136 tons of material; 848 agents were visited.

Products	Brands Registered	Brands Collected	Samples Collected	Number of Analyses	Number of Determinations*
Mixed fertilizers	333	322	1,128	480	5,760
Ground bone, tankage and fish	58	55	183	68	325
Nitrogen products, organic and mineral	56	50	307	195	396
Phosphoric acid products	28	26	111	29	116
Potash products	18	17	72	28	96
Dried, pulverized natural manures	23	22	101	23	115
Nitrate of potash	6	6	10	7	28
Miscellaneous	15	14	24	16	102
Lime products	36	34	72	39	334
Totals	573	546	2,008	885	7,272

*Not counting check tests or repeats.

During the period July 1, 1931, to July 1, 1932, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons) Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	39,689	1,957	3,386	2,725
Unmixed fertilizer chemicals and materials	20,325	1,350	1,476	534
Pulverized natural manures	1,939	40	27	53
Totals	61,953	3,347	4,889	3,312

Full details of the fertilizer and lime inspection will be found in Bulletins 65 and 66, Control Series.

Miscellaneous Analytical Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Cooperative chemical investigations have been carried on, as usual, with other departments of the Experiment Station, as well as with the Waltham Field Station and with County Agents. The character and extent of this work is shown from the following summary:

Celery leaves for mineral poisons	1
Complete fertilizers	1
Corn stover, ash analysis	33
Farm manure	1
Fertilizer chemicals and unmixed fertilizer materials	23
Hay, for partial ash analysis	59
Miscellaneous crops and crop residues for ash analysis	6
Oil emulsion	1
Soils, analysis of water extract of	15
Tomato pulp, dried, complete analysis	2

The usual variety of chemical work has been performed for farm organizations and state institutions, as well as individuals interested in agriculture. Reports of results have in all cases been accompanied by interpretations and advice with reference to the problems involved. This group includes the following materials:

Agricultural lime products	14
Ashes, cotton hull and wood	15
Complete fertilizers	20
Fertilizer chemicals and unmixed fertilizing materials	22
Insecticides and fungicides	3
Manures	8
Manufacturers' by-products	7
Miscellaneous	11
Peat products	19
Soils	37

Contact and cooperation with the Association of Official Agricultural Chemists has been maintained as in the past, in so far as rulings of the State Administration and the resources of the Control Department would permit.

Vegetation Pot Experiment with Phosphates. Season of 1932. (H. D. Haskins.) This experiment, comprising 101 pots in a study of the phosphoric acid availability of 20 different sources of phosphoric acid, has not reached the stage where positive conclusions are possible.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Study of the Effect of Plant Nutrients on Carnations and Roses Under Glass. (Harold E. White, Waltham.) Urea, Calurea, Cal-Nitro, and ammonium sulfate, when used as the source of nitrogen on a 4-12-4 basis, produced an average of 30 flowers per square foot of bench area, whereas sodium nitrate and calcium nitrate produced 25 flowers per square foot.

Where Calurea was used as a source of nitrogen in a 4-12-4 mixture, applied at the rate of from 1 ton to 4 1/2 tons per acre, there was a decrease of split flowers from 33 per cent to 5 per cent. This would tend to indicate that one means of lessening the tendency of carnations to split is by increasing the rate of application of fertilizers within certain limits. The production of carnation plants was increased from 18 flowers to 31 per square foot by increasing the rate of application of 4-12-4 from 1 ton to 4 1/2 tons per acre. Fertilizer applied at a higher rate than this resulted in a decrease in production. Carnations apparently will stand high application of fertilizers as long as the phosphorus and potash balance is maintained. Plots receiving as high as 10 tons per acre of a 4-12-4 showed no injury other than a reduction in production of flowers. The only exception was in the case of sodium nitrate where applications above 1500 pounds per acre resulted in a stunting of the plants, a reduction in the size of the flowers, and an adhesion of the flower petals. The adhesion symptoms did not occur in any other plots even though the rates of application were the same as for sodium nitrate; neither did dwarfing of the plants appear where the other materials were used in equivalent amounts. The soil reaction does not appear to be a factor where adhesion results from the excessive application of sodium nitrate, since in no case did the pH go above 7.0. The lowest pH, even where high applications of ammonium sulfate were made, did not go below pH 5.0. There was no noticeable effect of source of nitrogen or rate of fertilizer application on the rooting of carnation cuttings. Stem rot was present early in the season in the plots, but there appeared to be no correlation between feeding and severity of this disease on carnations.

Roses seem to give a better yield and make more vigorous growth where organic materials are used than when fed with straight commercial fertilizers. High application of chemical fertilizer reduces production and vigor of the plants.

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) In the F_1 generation there was no consistent segregation for rust resistance sufficient for definite determination of the resistance factor. For most of the inbred lines studied, resistance to susceptibility approached a 1:1 ratio. With the F_2 generation resistance increased and, while the percentage varied, there was an approximate ratio of three resistant to one susceptible for total resistance. Resistance was so variable that color could not be correlated with resistance. Commercial strains which have been used for breeding have continued to show complete susceptibility to rust. Crossing commercial strains, while resulting in increased vigor, did not make the progeny less susceptible. Resistant strains crossed with pink varieties have resulted in complete susceptibility, even in the F_2 generation.

Double-crossed progeny in the F_1 generation did not show noticeably increased resistance to rust over the single-crossed progeny. The ratio of resistant to susceptible plants in the F_1 generation in both crosses was about the same. Susceptible strains in the F_2 generation gave all susceptible progeny. Susceptible plants from the F_1 generation continued to breed true for susceptibility in the F_2 generation. Between eight and ten thousand plants were grown in the F_2 generation test; selections from these strains are being carried on for the F_3 generation.

DEPARTMENT OF HOME ECONOMICS

Bernice Wait in Charge

The Comparative Value of Milk and Tomato for Supplementary Feeding in Elementary Schools. (B. Wait and M. V. Cowing.) For the past three years the children in a small consolidated rural school have been given a supplementary mid-morning feeding at first of either milk or tomato and later of a combination of evaporated milk and tomato juice. The study is being continued for a fourth year by feeding the children of a control school to ascertain whether any results of the feeding which seemed apparent can be duplicated in this latter group. Whether the data obtained will confirm the observation that there was some improvement in the general well-being of the children as a result of the feeding of either the tomato or the milk or of both, or whether the apparent improvement was sufficient to be measured by the tests applied can not be stated until the analysis of these data has been more nearly completed.

The Value of Evaporated Milk for School Food Service. (B. Wait and O. A. Merriam.) This project is similar in purpose and in method to the above. Throughout two school years the children of the first four grades of the school in a small mill village have been given a mid-morning feeding of eight ounces of reconstituted evaporated milk daily. The general condition of these children at the beginning and the end of the school year as indicated by medical and dental examinations, and their growth, school progress, school attendance, and incidence of colds during the school year have been observed. These same observations have also been made of a control group of children of the same grades in a school in a neighboring village. As in the project above, the control group is being fed this year to ascertain whether any improvement observed in the general well-being of the children of the experimental group can be obtained as well in the children of the control school.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Technological Investigation and Nutritive Value of New England Fruit Products. (C. R. Fellers and J. A. Clague.) Apple juice extracted within a few seconds by means of a small centrifugal extractor proved to be a very satisfactory beverage, though differing materially in color, flavor, and consistency from pressed sweet cider. The fresh juice darkened rapidly and formed a fine sediment. Both freshly made and 24-hour-old juices had lost 10 to 30 per cent of the vitamin C content of the original fruit. Pasteurized cider and strained apple sauce retained practically no vitamin C, while benzoated cider and unstrained apple sauce retained 20 to 40 per cent of the vitamin C. In the Baldwin apple, the vitamin C is concentrated in the epidermis and in the fleshy cortex. The epidermis is about 4 times as active as the flesh near it, and 6 to 10 times as active as the flesh in the pulpy area near the core.

While the Baldwin apple is a rich source of vitamin C, the McIntosh is very poor. When 25 grams a day were fed to guinea pigs. there was some scurvy protection and bare maintenance of weight.

Baldwin apples had lost about 20 per cent of their vitamin C content after 4 to 6 months storage at 36° F.; after 8 to 10 months the loss had reached nearly 40 per cent.

Ten leading New England varieties are now being tested for vitamin C.

Manufacture, Preservation and Nutritive Value of Cranberry Products. (C. R. Fellers and J. A. Clague.) Approximately 50 varieties of cranberries were again examined chemically and made into strained and whole-fruit sauce. Many varieties were found unsuitable for manufacturing purposes. In fact, a blend of several varieties gives the best cranberry sauce in point of flavor. Data were collected on the manufacturing methods employed by canners and preservers of cranberry products. For canning cranberry sauce only well-tinned re-enameled cans will satisfactorily preserve the flavor and color for a year at room temperatures. Corrosion and perforation of the can, and discoloration of the sauce are greatly reduced at storage temperatures of 32° to 40° F. Either slow or quick-frozen cranberries can be used for sauce manufacture. The canned sauce made from frozen berries kept in storage for one year was fully equal in quality to that made from fresh fruit.

Vitamin studies made by P. D. Isham, aided by funds furnished by the American Cranberry Exchange, have further proved the high antiscorbutic value of the fresh and frozen cranberry and whole-fruit cranberry sauce. Strained sauce, pasteurized juice, jelly, and evaporated whole cranberries retained very little vitamin C. Cranberries were shown to contain about 0.2 rat unit per gram of vitamin A. Negative results were obtained for vitamins B, D, and G.

Additional blood and urine examinations were made on young men fed measured quantities of cranberries. The blood alkali reserve was not significantly decreased unless 5 ounces or more of cranberry sauce was eaten. The conjugation of benzoic and quinic acids in the body produced urinary acidities in proportion to the amounts of cranberry ingested, though 5 ounces or less of cranberry sauce produced relatively slight increases in either the H-ion concentration or the hippuric acid. These results indicate that moderate or even generous servings of cranberries may be eaten without fear of reducing the blood alkali reserve to a dangerous degree.

Cranberry juice has been prepared both by the cold-pressing and heat-extraction methods. For cold-pressing, the berries should be ground and allowed to stand in a cool place for 12 to 24 hours to increase the color of the pressed juice.

The yield is about 3.5 gallons of pure juice to 50 pounds of fruit. The clarified diluted juice with the addition of sugar makes a very satisfying beverage and one not at present marketed. The heat-extracted juice is already being manufactured on a commercial basis in this State.

Cranberry jelly has never been a satisfactory commercial product. The jelly is soft and watery. This objection has been entirely overcome by treating the cold-pressed or heat-extracted juices with pectinase enzyme to remove the quick-setting cranberry pectin. This is followed by filtration and the addition of citrus or apple pectin. A perfect jelly retaining all the flavor and color of the cranberry is thus obtained.

Effect of Microorganisms on the Jellying Power of Fruit Juices. (C. R. Fellers, J. A. Clague and R. L. France.) The several species of yeasts and bacteria employed to date do not decompose pectin in fruit juices. However, several species of Penicillium and Aspergillus are very active pectin decomposers. Juice or pulp harboring these actively growing molds will not make satisfactory jelly or pectin.

Utilization of Onions by Canning and Drying. (C. R. Fellers.) This project has been inactive during the year except insofar as canned, dried, and pickled onions, previously packed, have been examined for keeping quality. There has been much commercial interest shown in the onion powder from cull onions which was developed several years ago.

Utilization of New England Fruits in Ice Cream. (C. R. Fellers and M. J. Mack. A report of this work was published in July as Bulletin 287. This co-operative project has been continued with a view to ascertaining whether strawberries still retain vitamin C after freezing and storage and incorporation into ice cream. Results clearly indicate that the high vitamin C content of fresh strawberries is retained in both frozen strawberries and strawberry ice cream.

Research on Dates. (C. R. Fellers, J. C. Clague and M. M. Cleveland.) The mineral composition of dates was determined and published in *Industrial and Engineering Chemistry, Analytical Edition*, 4:267-268, July 1932.

The souring of dates was found to be due to the growth of sugar-tolerant yeasts. Some of the results were published in the *Journal of Bacteriology* 23:63, January 1932.

This work was made possible by a grant from the Hills Brothers Company of New York.

Vitamin Content of Blueberries. (C. R. Fellers and P. D. Isham.) Native, Maine, and Newfoundland blueberries were examined for vitamin C content, funds to help in this work having been furnished by the Birdseye Laboratories of Gloucester. The native tall-bush blueberry, fresh, frozen, or canned, was a good source of vitamin C, about 4 to 5 grams daily sufficing to protect guinea pigs from scurvy. However, the Maine and Newfoundland low-bush blueberries were not over one-third as active in this vitamin.

Effect of Fertilization on Vitamin A and C content of Asparagus. (C. R. Fellers, R. E. Young and P. D. Isham.) With the financial assistance of the Potash Export Company, My., asparagus grown at the Waltham Field Station was tested for vitamins A and C. The first season's results show that asparagus is a rich source of vitamin C, from 2 to 2.5 grams daily fully protecting guinea pigs from scurvy. The fresh asparagus also contained 5 to 7 units of vitamin A per gram. No conclusions may yet be drawn as to the effect of fertilizer treatment on vitamin content.

Canned Red Squill Rat Baits. (M. G. O'Connor and E. M. Mills, Bureau of Biological Survey, U. S. D. A.) This research, financed by the K-R-O Company of Springfield, Ohio, has shown that beef or horse meat, whiting, mackerel, haddock, and cereals, when mixed with red squill powder and canned, proved to be acceptable yet toxic baits for rats. Proper sterilization processes have been worked out for these canned baits.

DEPARTMENT OF OLERICULTURE

Ralph A. Van Meter in Charge

Asparagus Investigations. (Robert E. Young, Waltham.)

Fertilizers. The asparagus plots located at Waltham on a rather heavy soil did not produce as high yields in 1932 as those located on the lighter soils at Concord and Eastham. The spears at Waltham were very small, but the number of spears per plant was large. Older asparagus growing in another bed adjacent to these plots produced a large percentage of fancy spears, while almost no spears large enough to be graded as fancy were produced on the fertilizer plots. Nitrate of potash and sulfate of potash did not give as good results as muriate of potash. The difference in yield of the plots receiving the various nitrogen carriers was insignificant. Results this year show that potash is necessary for high yields.

The plots at Eastham, Massachusetts, on a light, gravelly soil gave very good results. Yields were high and the proportion of fancy spears was much greater than at Concord or Waltham. The plot receiving seaweed and superphosphate remains the highest-producing plot in the experiment, probably due to the capacity of this plot to hold moisture and plant food. Ten of the plots are duplicated on an acid soil. Some of the fertilizers gave better results on the acid soil, but ammonium sulfate gave only about 60 per cent as great a yield as on the regular plot.

The plots at Concord were cut for a period of two weeks this year. Last year they were not cut, due to poor growth of the previous season. The yield was very good for the short period of harvest. The plot that produced the highest yield was one receiving cottonseed meal as the source of nitrogen. This was followed closely by the plots which received the nitrogen as sulfate of ammonia and the phosphorus as basic slag. The remainder of the plots are grouped very close together in yield. The plot receiving no potash was notably low. Acidity tests made late in the fall show that the average pH has been raised from 4.5 to about 5.8.

In general the results obtained this season are much more promising than those of last season. There were some substitutions made in the fertilizer materials used, one being the use of calcium cyanamid, superphosphate, and potash in place of a mixture of ammonium phosphate and potash. The cyanamid was applied at the regular time, June 20. At that time there was a very heavy crop of weeds about three inches high covering the ground. A few days after this application of about 750 pounds of calcium cyanamid per acre, the weed growth had been completely killed. It apparently did not affect the asparagus plants.

Depth of Planting and Height of Cutting. The most significant result of this experiment seems to be the increased mortality where the asparagus roots are planted 6 and 8 inches deep. The decreased number of plants in these plots has reduced the yield. The roots planted at the shallow depth of 2 and 4 inches produced by far the most asparagus. If the yields are computed on the basis of a 100 per cent stand, however, the roots planted 8 inches deep rank first in yield, followed by the plots where the roots were planted 2, 4, and 6 inches deep, respectively. A

comparison of the stand counts in 1931 with those in 1932 shows that in the plots where the roots were planted 2 and 4 inches deep there was almost no loss of plants; while the plots where the roots were 6 to 8 inches deep continued to lose plants, there being approximately a 6 per cent loss in the latter case.

Of the three plots where the spears were cut with 4, 8, and 12 inches green, the largest yield was obtained from the plots cut with 12 inches green, and the plots with 8 inches of green were next. Yields from the plots cut with 4 inches of green were 11 per cent below the yields of the 12 inches of green. The yields this year were about the same as in 1931 except that the spread between the 4 inches and the 12 inches green was not so great. Definite conclusions cannot be drawn until the results of two or three seasons are available.

Seed Improvement. (Robert E. Young, Waltham.) Selfing to obtain pure lines was continued on five of the most promising strains of blue Hubbard squash. Some of these strains are nearly pure as shown by the uniformity of shape, color, wartiness, and thickness of flesh. These strains are losing vigor in that they do not produce yields equal to those of commercial strains. Some F_1 plants were grown from the cross of the most promising strains last year. The plants were selfed in order that a pure strain may be obtained if they continue to show promise.

The 1931 selections of Horticultural beans grown this past season proved to be a great improvement over any commercial variety that has been tried here. Two of these selections were very superior, and it is the intention to develop them further.

The market gardeners purchased about 750 pounds of the Field Station Hutchinson carrot seed this year. It is reported to be superior to commercial strains. There is some variation in the length of the carrot when it is grown in various types of soil. Plenty of this seed is available for distribution in 1933. The parent stock is being maintained at the Field Station to insure the same quality of seed from year to year.

The red sport of Oshkosh pepper that has been grown at the Field Station for the past few years has now been named the Waltham Beauty. The uniformity of the fruit of this pepper was greatly improved by the selections made in 1931. In 1932 there were plants among the selections that bore 20 marketable fruits. Plants grown on a one-eightieth acre plot for yield data produced an average of 12 peppers per plant, and the average weight of the peppers was 3.7 ounces. Selections were continued to improve the uniformity of the plants in height. Crosses made in the greenhouse last winter between the Waltham Beauty and the California Wonder, in the hope of producing a larger pepper, increased the size but at the expense of yield. As the Waltham Beauty seems superior to the varieties grown by the market gardener, it was decided not to wait until the pepper is perfected to distribute samples of the seed.

An ample supply of seed of the Bel-May lettuce is now available. Last season, 125 pounds of seed were grown in California for the Boston Market Gardeners Association. Plants are now being grown to maintain the seed stock, and from these selections will be made in an attempt to improve the frame formation.

Selections have been continued to improve the color and flesh of the Wyman Crosby beet. This variety has already proved to be very uniform in shape and size. The beets produced from the stock seed are uniform in shape and size and maintain their quality until quite large. Selections were made last season on the basis of size and color, as there seemed to be some indication of a correlation between them.

Systematic and Quality Studies of Varieties of Sweet Corn. (G. B. Snyder.) In the trial plots, 231 lots of sweet corn including 82 different named sorts were grown. Detailed records of each lot were taken in order to allow for definite classification and rating as commercial varieties for Massachusetts market gardeners. Many lots having distinct names were found to be either very similar to or synonymous with older standard varieties. Comparatively few of the varieties studied were found to be satisfactory for culture by the market gardener from a consideration of maturity, yield, size of stalk, size of ear, and color, size, and quality of kernel.

Refractive indexes and percentage-of-sugar readings were taken for 211 lots, 20 readings being taken for each lot. In the pre-milk stage of development sugar ranged from 12 to 16 per cent, and from pre-milk to soft-dough development varieties differed markedly, the high point in sugar ranging from 16 to 29 per cent. Strains of a variety, however, deviated very little from the average for the variety in percentage of sugar.

This year was the first of a three-year project.

Dark Center or Internal Breakdown of Swede Turnips. (G. B. Snyder and R. W. Donaldson.) Dark center of the Swede turnip is apparently physiological in character and non-parasitic. Histological studies indicate the condition as brownish or water-soaked areas in the parenchyma tissue between the vascular strands. The tissue of the cortex and cambium is not affected. In the advanced stages of dark center, the affected tissue becomes pithy and woody.

Field studies of dark center did not show any relationship between the condition and fertilizers, soil acidity, soil type, or crop rotation. A definite relationship, however, was noticed between soil moisture and dark center.

Series of crocks were set up in which varying quantities of animal manures and peat were applied to soils taken from infected fields in Berkshire and Barnstable Counties. In each series the soil moisture was regulated at low, medium, and high points. In every case the high organic soils having a medium to high moisture content produced plants showing little to no dark center. The low organic soils having a low percentage of moisture produced plants, the roots of which were decidedly affected by the disorder.

Taxonomic Studies of Eggplants. (G. B. Snyder.) During the past five years, 105 different named lots of eggplants have been under observation in the trial plots. Detailed records have been taken of each lot for plant and fruit characters, disease susceptibility, and commercial adaptability. From these observations and records a systematic monograph is being prepared.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY

J. B. Lindsey in Charge

The Effect of Fertilizer and Cultural Treatment on the Composition of Havana Tobacco. (E. B. Holland and E. Bennett.) Various grades of Havana tobacco raised on the station plots in 1931 have been analyzed with a view to determining the effect of different amounts and forms of applied nitrogen on the composition of the web of both cured and sweat samples. The scope of the work has been broadened to include the determination of carbohydrates, with the expectation that additional studies may show some correlation between the nitrogen-carbon ratio of the web and its free-burning qualities.

To supplement this investigation popular brands of smoking tobacco and of cigarettes have been purchased in the local market and submitted to analysis.

The results show marked differences in the pipe tobaccos but a reasonable uniformity in the cigarette tobaccos.

Oil Sprays. (E. B. Holland.) Miscibles were prepared from five different lubricating oils ranging from spindle oils to a medium turbine. The process employed was the so-called spontaneous method using triethanolamine oleate as the emulsifying agent. The miscibles were applied in the orchard on the basis of 3 per cent oil by weight and gave satisfactory control of mites (index) in all cases with no apparent injury to buds or retardation of growth. The heavier, more viscous oils required a larger amount of emulsifying agent at an increased cost and were no more effective.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-Legumes Under Certain Defined Agronomic Conditions. (F. W. Morse.) The crops grown this year (1932) were Hungarian millet and soy beans as non-legume and legume. Nitrogen was applied this year to Plots 5, 8, and 10, while Plots 7 and 9 were continued without any as in the past 50 years. This was the ninth crop since the beginning of this experiment, during which period Plot 6 has not received nitrogen while in previous years it had been dressed with ammonium sulfate like Plot 8.

Dry Matter and Nitrogen Removed from Non-Legume and Legume Areas in 1932
(Pounds per acre)

	Without Nitrogen		With Nitrogen	
	Dry Matter	Nitrogen	Dry Matter	Nitrogen
Hungarian Millet	3464	28.24	5385	52.78
Soy Beans	4029	104.77	4377	99.43

The non-leguminous millet responded to the nitrogen fertilizer with an increase of 1921 pounds of dry matter, equivalent to 2260 pounds millet hay per acre. The gain in nitrogen was 24.5 pounds, which is only 55 per cent of the 45 pounds applied per acre.

The leguminous soy beans gained 348 pounds of dry matter when nitrogen was applied, but the crop contained less nitrogen than that grown without any nitrogen in the fertilizer. The failure to take up nitrogen from the fertilizer has been observed in previous seasons with clover.

A summary of the nine crops grown on the legume sections of all the plots is here presented for each year of the experiment.

Dry Matter and Nitrogen removed from Legume Areas in 9 Years
(Pounds per acre)

		Without Nitrogen		With Nitrogen	
Year	Crops	Dry Matter	Nitrogen	Dry Matter	Nitrogen
1924	Clovers	3865	106.1	*3916	100.6
1925	Corn	3419	59.4	3422	58.5
1926	Soy Beans	3491	79.6	*3681	87.9
1927	Corn	2366	39.4	2353	40.9
1928	Clover and Weeds	2658	39.0	*2828	38.7
1929	Clover	3952	91.6	3624	81.3
1930	Millet	6187	78.9	*6920	89.5
1931	Peas and Oats	2510	44.6	2579	46.8
1932	Soy Beans	4029	104.8	*4377	99.4
	Total	32477	643.4	33700	643.8

*Nitrogen applied in each of these years at the rate of 45 pounds per acre.

The net gain in nine years by the application of 225 pounds per acre of nitrogen was 1223 pounds of dry matter, while the nitrogen contained in the crops practically balanced. The fertilizer nitrogen appeared to stimulate growth at some stage, due possibly to its immediate availability, without ultimately increasing the content of the element except in the non-leguminous crops interspersed in the series. The leguminous crops from the plots without nitrogen, four times out of six, contained more nitrogen than those from the nitrogen group.

The results of this fertilizer experiment are now being prepared in more detail for publication. They suggest a new comparison between atmospheric nitrogen compounds synthesized by bacteria and those synthesized by factory processes by continuing the legumes and non-legumes, but substituting the newer nitrogen compounds for the former standard fertilizers.

Chemical Study of Cranberries. (F. W. Morse.) Twenty-three varieties of cranberries were analyzed, ten of which were from Wisconsin and thirteen from New Jersey. The samples were procured by Dr. H. J. Franklin in connection with his comparative studies of cranberry varieties. No information was available regarding dates of picking from the vines.

The analyses were made during January of this year (1932), and the berries were removed from cold storage as needed. Water, total sugar, and total acid were determined. Eight varieties were below 3 per cent in sugar content, which indicates fruit immature when picked. Eleven were between 3 and 3.5 per cent and one contained 4 per cent total sugar. Total acid ranged from 2.05 to 2.71 per cent which is within the limits found in past seasons.

Two varieties were notably superior in the proportion of sound fruit in January. Searls Jumbo from Wisconsin and Budds Blue from New Jersey were more than 85 per cent sound when sorted by hand. Fourteen were less than two-thirds sound, which shows the risk in holding cranberries in storage to extend the market period.

The two varieties above named illustrate the comparatively narrow difference in chemical composition between extreme types of cranberries. Searls Jumbo is a juicy berry of high quality. Budds Blue is dry and firm in texture. Analysis gave the following results in percentages.

	Water	Total Sugar	Total Acid
Searls Jumbo..	87.9	4.02	2.33
Budds Blue.....	86.6	2.61	2.20

Astringent matter was determined in several varieties, of which these two represented the extreme range — Searls Jumbo, 0.19 per cent; Budds Blue, 0.37 per cent. The astringent matter in the cranberry appears to consist of a glucoside with a bitter taste rather than tannin, although qualitative tests show traces of tannin to be present.

Quinic acid was determined in 13 of the varieties by the tentative method mentioned last year. The range in approximate percentages was from 0.38 to 1.03 per cent. The two varieties mentioned above were practically alike, with approximately 0.7 per cent of the acid.

In the course of the cranberry studies, a quantity of the cranberry wax has been accumulated for the purpose of studying its properties.

Milk Substitutes in the Growing of Young Calves. (J. B. Lindsey.) This project has been completed and the manuscript prepared for publication. The general conclusion was that it is quite desirable to feed calves some liquid food until they are two months of age, and the time can well be extended a month

or more in case of delicate calves or when an extra growth impetus is desired. Nothing better was found for this purpose than powdered skim milk, now easily obtainable in the market at a reasonable price, followed later by white fish meal combined with our grain ration No. 5. The detailed method of procedure is given in the publication.

Two Systems of Dairy Cattle Feeding — High Roughage and Low Grain versus Low Roughage and High Grain. (J. B. Lindsey and J. G. Archibald.) This investigation has been completed and the results published in Bulletin 291.

Mineral Requirements for the Growth of Dairy Heifers. (J. B. Lindsey and J. G. Archibald.) Eighty-eight metabolism balance trials have been completed with twelve heifers on high and low phosphorus rations. The results of seventy-two of these trials with eight of the heifers have been calculated and sufficiently interpreted to enable determination of the next logical step in the investigation; but publication of even tentative conclusions at this time is not deemed justifiable.

Studies in the Chemistry of Pasture Grasses. (J. G. Archibald and E. Bennett.) A final report of three years' work on the chemical composition of grass from pasture plots managed according to the Hohenheim system appeared in the *Journal of Agricultural Research* 45: 627-640, November 15, 1932.

Results of a study of the distribution of the different forms of nitrogen in pasture grass have been brought together in an article entitled "Nitrogen Partition in Pasture Grass", which has recently been submitted for publication in the *Journal of Agricultural Research*, together with a companion article entitled "Influence of Drying and Grinding upon the Total, Amino and Ammonia Nitrogen Content of Grasses."

Field work in connection with the survey of natural pastures throughout the State was completed this year. One hundred samples of grass have been collected from typical unfertilized pastures on predominant soil types in the five western counties of the State. The analytical work on these samples is in progress and will be completed within a few weeks.

The study of the chemical composition of various species of grass has been continued this year. Forty additional samples from well-established plots of timothy, red top, Kentucky and Canada bluegrass, orchard grass, sheep fescue, Rhode Island bent, and white clover have been secured during the year, and reliable data are gradually being accumulated. The work will be continued at least another year before a formal report is made. However, the following tentative observations seem warranted at this time:

1. Orchard grass (*Dactylis glomerata*) has a remarkably high mineral content, phosphorus being about double that found in any other grass studied, and calcium being considerably higher than in most of the others.

2. The bent family of grasses (*genus Agrostis*), represented in this study by red top (*Agrostis alba*) and Rhode Island bent (*Agrostis canina*), seems to be characterized by a high content of calcium.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The experiment station orchard produced another good crop of peaches in 1932 following a remarkably mild winter. The lowest temperature reading in the orchard was exactly zero. During the ten years that this orchard has been of bearing age, the crop has failed only in 1924 and 1927, the cause of failure being

winterkilling of the fruit buds. Evidently the killing point is usually close to -15° F. Buds, especially of bud-hardy varieties, may withstand lower temperatures, while those of the more tender varieties may be badly killed at higher temperatures. The severity of bud killing depends on (1) the minimum temperature, (2) the variety, (3) the condition of the tree, and (4) conditions prevailing at the time of the temperature drop, such as wind, the rapidity of the drop, and the duration of the low temperature.

The apple crop was about 60 per cent larger than that of last year but was exceeded by that of 1930 also by about 60 per cent. Damage from insects and diseases in all well-sprayed orchards was unusually light.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw.) Due to financial stress the Department has been obliged to allow the control of the main orchard of this project to pass to a commercial grower. Limited observations will still be made, but detailed experimental studies become impossible. Applications of muriate of potash to certain rows have not yet shown clearly that the "tip burn" referred to in the report of last year is due to potash deficiency. Observations on this will be continued. It is evident that water supply is a factor, but it is possible that lack of potash may also be a factor.

The young orchard of McIntosh and Wealthy on East Malling stocks set in 1928 continues to develop in a satisfactory way. It bore a scattering crop this year. McIntosh on Malling Stock 1 gives indications of being superior in early production, while Wealthy on the same stock does not produce so much on account of the very small trees. Stock 16 maintains its position as a standard stock and has produced well. Stock 9 promises to be a good dwarfing stock. The largest crop of Wealthy was on trees on Stock 4, and only McIntosh trees on Stock 1 exceeded those on Stock 4. This stock is not very highly regarded in England and may develop some fatal weakness, but experience thus far seems to indicate that here it is a good stock for producing large trees and for early production with these two varieties.

These stocks are being further multiplied, and more extensive tests of our desirable varieties on them are planned. It seems possible that some of them may be desirable for producing semi-dwarf trees, free from the objections to dwarf trees, which may have commercial value.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French.) The set of photographs and technical descriptions of more than 100 commercial varieties of apples referred to last year has been practically completed. Work along a similar line with commercial varieties of cherries has been started. Trees or buds of nearly forty varieties have been assembled. Seedlings of Japanese flowering cherries have been used as stocks. Certain types of this species produce viable seeds abundantly and give vigorous seedlings resembling Mazzard stocks. Further experience will show whether these are desirable for cherry stocks.

The usual certification work of the Massachusetts Fruit Growers' Association and the inspection of nursery trees for trueness to name have been continued although in somewhat reduced volume as compared with earlier years, due to the reduced demand for trees. The significance of this work is shown in the almost complete absence, now, of misnamed trees in the nurseries examined; whereas in the early years they were present, literally in thousands. The nurserymen report a marked reduction in the complaints of misnamed trees received from customers during the last few years. Such complaints must practically disappear in the future. The nurserymen having these examinations represent a rather small proportion of the total number; but the influence of this work extends beyond the

nurseries actually examined and there can be no doubt that the number of misnamed trees sold has been greatly reduced.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) Evidence has been obtained that in peaches there is linkage between the gene controlling stone adhesion and the gene controlling flesh toughness, with about 8 per cent crossing over. The Champion variety has an albino lethal character which acts as a simple Mendelian recessive. Among certain seedlings a new combination of leaf characters has appeared. Some individuals have very wavy leaves, deeply serrate margins, and globose glands. A paper on "The inheritance of certain characters in the peach" which is to appear in the 1932 *Report of the American Society for Horticultural Science*, will discuss these observations in more detail.

The breeding work was continued in the spring of 1932. This work was planned so as to give further information concerning the linkage relations between stone adhesion and toughness of flesh. Favorable weather conditions prevailed during the breeding season and a good crop of pits was obtained.

The two orchards of seedling peaches planted in 1928 had to be removed in the fall of 1932 because of a severe infection of peach yellows.

As a result of the peach breeding work in 1931, about 300 seedling peach trees are in the nursery ready to be set in the orchard in the spring of 1933.

Testing Methods of Pruning. (J. K. Shaw.) One of the orchards involved in this work has passed into the hands of a commercial grower for reasons previously mentioned. Some observation on the orchard may still be made. Work in the other orchard is still continued with no change in the trend of results.

Effect of Pruning Bearing Apple Trees. (J. K. Shaw and O. C. Roberts.) This experiment in an old bearing orchard has continued as in earlier years, comparison being made between heavy, light, and no pruning. Sizing and grading tests show in some cases better color and larger size in the apples from pruned trees and occasionally less insect infestation and disease, but the differences continue to be less than most fruit growers would expect.

Observations have been extended to include certain Rhode Island Greening, Wealthy, Ben Davis, and McIntosh trees, 35 years old, some of which are moderately pruned while others are left unpruned.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) The amount of nitrate of soda applied to the sod plots was increased in the Spring of 1932 from 300 to 400 pounds per acre. There is some evidence that this may have resulted in yields larger than they would have been without this increase. Yet the plot in cultivation with nitrate continued to make a better showing; this gives further evidence that the sod-nitrogen program will not, over a period of years give maximum yields. The McIntosh trees on the cultivated nitrate-potash plot continue to yield better than those on the similar plot receiving nitrate alone, while the Baldwin trees do not. The increase in McIntosh is about 70 per cent, while the Baldwin trees have shown little or no increase. Further evidence is needed before it is safe to conclude that McIntosh has more definitely a potash requirement than Baldwin; yet it may be true.

The younger orchard included in this project has passed out of our control as previously stated.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw.) The fertilizer treatments were continued as in previous years. The grass has been allowed to grow and the white clover has almost disappeared from

the phosphorus-potash-lime plots. These plots continue inferior to the complete fertilizer plots in yield. There is no conclusive evidence that the white clover brought in by the phosphorus-potash-lime treatment has benefited the trees, yet the trees have apparently produced better than they would have done had no fertilizer been applied. Wagener seems to have suffered more from lack of nitrogenous fertilizers than have Oldenburg and Wealthy.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw.) This project has continued on the modified plan of fertilizing only in the off-bearing years. A complete fertilizer is used which contains nitrate of soda at the rate of 10, 17½ and 25 pounds per tree. The orchard is in sod. The crop in 1932 was less than that of 1930. This may have been due to weather conditions, the probable cause of the rather light Baldwin crop in 1932, or the omission of fertilizer may been have a factor. It is uncertain as yet whether this omission has improved the appearance of the fruit. Yields continue to be larger with larger amounts of nitrogen, and there is no marked difference in color of fruit.

Comparison of Cultivation and Heavy Mulching for Apples from the Different Plots. (J. K. Shaw.) The cultivated plots which received no fertilizer before 1931 were fertilized with nitrate of soda this year as in 1931. There is an apparent increase in yield of McIntosh, but Wealthy shows little if any increase. The yield of McIntosh, considering the smaller size of the trees, is now nearly if not quite as good as that from the mulched trees. The standard Wealthy trees on the cultivated plot with nitrate show some gain from the nitrate but those on doucin stock do not. This may be because they were already producing up to their limit. The comparison will be continued.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) The own-rooted McIntosh and Wealthy trees planted in 1931 have made fair growth, and the fertilizer applications were continued the same as last year. Conclusions as to whether these trees will behave the same as those previously grown on this field cannot yet be drawn.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw.) Further studies on the effect of acidifying soil from the long-time fertilizer test field known as the North Soil Test by applications of sulfur showed that lowering the pH value below 5.0 usually injures the growth of the seedling peach trees used as indicators, while lowering it below 4.0 kills the trees. The addition of mineral fertilizers is likely to be of little or no benefit, while the addition of organic ammoniates favors growth even in rather acid soils. Trees in soil from an apple orchard where apple trees are growing well, grew well under a pH of 4.2; however, when the pH was lowered to 3.8 the trees failed to grow. Raising the pH by additions of lime favored growth as in previous years.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) This project has been carried on as in past years. There seems to be no evidence that lime has been of any benefit to the trees. It is possible that the addition of potash to nitrogen has now increased yields though there was no evidence of it in the earlier years. No indications of benefit to the trees from the application of phosphorus have yet appeared. More data and a careful analysis of all of it is necessary before final conclusions can be drawn.

Study of Varieties of Fruits. (J. K. Shaw and O. C. Roberts.) More new varieties came into bearing than in any previous year. Some are promising but few will take any prominent place among the standard varieties.

The Macoun apple bore more abundantly than in previous years. It is of good size and is nearly, if not quite, as good in quality as McIntosh. It is a real winter apple and fairly attractive in appearance. Its very short stem will cause no stem-bruises in the package. It is superior to Cortland in most respects. It seems to be the most promising candidate for a place as the much desired "Winter McIntosh."

Lobo is very attractive in appearance, being of a clear bright red but its quality is much inferior to McIntosh. As it is of nearly the same season it seems doubtful whether it can find a place in Massachusetts.

Early McIntosh and Milton showed no distinct superiority over previous years and it seems doubtful whether either becomes very valuable here.

Lodi is larger than Yellow Transparent and probably will stand handling a little better, but varieties of this type do not seem to be now in favor.

A red sport of Gravenstein originating in Ashby came into bearing this year. It is similar to the Washington type sent out by the New York Fruit Testing Association but does not seem in any way superior to it. Another sport, received from Lunenburg, while of somewhat higher color than Gravenstein, shows too little superiority to be very valuable.

Gallia Beauty again proved far superior in color to both Rome and Red Rome. The basin is wider, deeper, and more abrupt than in Rome, but otherwise it is similar in tree and fruit. There seems to be good reason why Gallia Beauty should replace Rome where such a variety is desired.

Melba is of Duchess season and superior to it for eating. It ripens unevenly and does not stand handling well. It may have value for local and roadside stand trade. Brock, Joyce and Pedro, three other McIntosh seedlings originating at Ottawa, are inferior in color and not too good in quality.

Scions claimed to represent a red and a blushed strain of McIntosh, topworked in the same tree, bore this year and proved the claim well founded. Apples of one strain were clearly striped and splashed while those from the other showed no sign of stripes or splashes. There was little difference in the total amount of color, yet the blushed strain is probably more desirable.

The raspberry variety plantation suffered badly from winter injury in 1931-32. Early in the spring the canes seemed in good condition but the leaf buds failed to start and the canes died back or were entirely killed. Some varieties suffered more than others. Newburgh and Monroe showed little or no injury. Possibly the rather severe cold in late winter and early spring following an unusually mild winter caused this injury.

The following varieties of red raspberries, originated at the Geneva New York Experiment Station, fruited in 1932:—

Newburgh has shown no mosaic as yet though other varieties located nearby have suffered more or less severely. It is vigorous, a good plant maker, and a heavy producer in mid-season of large firm berries of good quality. It is very promising.

Monroe (No. 2568). This variety also has as yet shown no mosaic diseases. It is vigorous, a good plant maker with practically smooth canes. It is a good producer, ripens its large, attractive, firm fruit early, and is of good quality. It is promising.

Nos. 2563, 2564, 2490 and 2491. These are similar to Monroe but all have suffered from mosaic diseases. The fruit ripens later and is poor in quality. They do not promise well here.

Some other varieties which fruited this year are as follows:

Lloyd George is vigorous and a good plant maker. It has not suffered from

mosaic but has shown some cane and spur blights. It ripens early and produces fairly well; the fruit is very large and of fairly good quality. It tends somewhat to be an everbearer. It should have value for the home garden.

Viking is vigorous and a good plant maker but suffered much from mosaic and winterkilled badly, seriously reducing the yield. When it does not winterkill it produces heavily of medium to large, firm berries of good quality in mid-season.

Chief is vigorous, a good plant maker, and has shown no mosaic. Fruit medium to large and of excellent quality. It is a good producer in mid-season, and seems very promising.

During the past season 41 varieties of strawberries were under observation. The following seemed to have desirable characteristics:—

Aberdeen is vigorous and a good plant maker. It is productive. The fruit is medium to large in size, attractive, medium to dark red in color, ripens from mid-season to late. It is worthy of a trial for both commercial and home use.

Bliss is one of the varieties originated at the New York Experiment Station. It is vigorous and a good plant maker, but somewhat susceptible to leaf spot. It ripens in late mid-season. The berries are large, attractive and of good quality.

Bouquet, also from the New York Experiment Station, is similar to Bliss but is earlier in season and seems to produce more heavily.

Commonwealth is an old variety but still worthy of consideration as a late variety which is its outstanding feature. It is moderately vigorous with light green foliage. It is fairly productive of large conic berries of fair quality.

First Quality is another old variety which maintains its popularity mainly because of its high quality. It is a fairly good producer of medium-sized berries in mid-season. It is susceptible to leaf spot.

Howard 17 (Premier) is too well known to need recommendation here.

Howard Supreme (Howard 25) is a newly introduced variety which continues to be one of the highest producers in the plantation. It is vigorous, dark green, and an excellent plant maker. The fruit is medium to large, dark red with red flesh and of good quality.

Mastodon continues to be the outstanding everbearer in the plantation. It is a good plant maker and a good producer of medium to large berries.

Steven's Late Champion is a good late strawberry but only fairly productive.

The following varieties are of questionable value in Massachusetts for the reasons given:

Beacon - lacking in vigor and a poor producer.

Dunlap - small size of fruit.

Edmund Wilson - poor producer.

Improved Heflin - lacking in vigor, fruit small and of mediocre quality.

Town King - very poor in quality.

May Beauty - lacking in vigor; not productive and of only fair quality.

King Edward - excellent in quality and size, but lacking in productiveness; of value only for the home garden.

Marshall - the standard of quality but extremely unproductive.

Some other varieties grown, but concerning which there is yet insufficient evidence to judge their true worth, are seven varieties from the New York Experiment Station: Caledonia, Camden, Clermont, Culver, 4433, 4734, and 4813; also the Jupiter and Wyona.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) This project is concerned with the effect on fruit-bud formation of nitrogen applications at various times during the latter part of the growing season. It was continued

during the past season along lines similar to those of the past four years. There has been no measurable effect where the plants are grown on the hill system with plenty of space between the plants.

A new bed was set in the spring of 1932 in which runner plants were developed and treated with nitrogen-carrying fertilizers. Nitrogenous fertilizers were also applied to alternating sections of strawberries in matted rows to study the effect of crowding upon nitrogen response. All plots are duplicated five times and all receive phosphorus and potassium.

Bud Mutations. (J. K. Shaw and W. H. Thies.) The collection of bud mutations of apple varieties was maintained. It will be several years before they come into bearing so that any persistent characteristics and their value can be determined.

Storage of McIntosh Apples Under Various Conditions. (O. C. Roberts cooperating with C. I. Gunness and W. R. Cole.) This project involves a study of the effect of the "blast" system of cold-air distribution on the keeping of McIntosh apples. A study is also being made of the optimum humidity for the satisfactory storage of apples in the cold storage and the air-cooled storage. Observations are being made in several commercial refrigerated and common storages in addition to those made in the college plant.

Study of Various Spray Materials. (O. C. Roberts cooperating with A. I. Bourne.) This is a continuation of the work that has been carried on here for several years whereby various spray materials on the market are given practical tests in the orchard to determine their efficiency and safety to the trees. Several of the wettable sulfur compounds appear to be suitable substitutes for liquid lime-sulfur in the post-calyx applications.

Blueberry Culture. (J. S. Bailey.) The propagation of blueberry plants was continued to increase the supply of plants, particularly of the newer varieties.

In the spring of 1932 a start was made on the establishment of a large plantation for the study of the cultural requirements of the blueberry. Observations on the relation of height of water table to the growth of blueberries were begun in this plantation.

The variety blueberry plantation was considerably enlarged to facilitate the more extensive testing of varieties under local conditions.

Cross Pollination and Sterility Studies with Certain Apple Varieties. (F. C. Sears, O. C. Roberts and others.) Work on the question of pollination of apples was continued for the eighth season. Special emphasis was placed on Macoun and Cortland, the two new varieties about which orchardists are most anxious to secure information. Both these varieties seem to be promising as pollinators for other varieties, but the evidence so far would seem to indicate that Cortland is inclined to be self sterile, like its parent the McIntosh.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays.) Non-broody and intense broody lines are continued. Both lines are being selected for the same degree of early maturity, intensity, absence of winter pause, and persistency. These lines will eventually differ only in the presence or absence of the broody instinct during the pullet laying year. In the 1931 generation there were 43 birds in the non-broody line. Of this number, 33 or 76.74 per cent were non-broody the first year and

their average annual egg production was 230 compared with an average production of 208 eggs for the 10 individuals going broody. The broody line was made up of 30 individuals. Three, or 10 per cent, were non-broody the first year. The mean egg production of the 30 birds was 177.

Deferred broodiness or the failure of the broody instinct to appear until after the first laying year causes considerable difficulty in the selection of breeding stock that is phenotypically broody or non-broody in the two lines.

The study of the mode of inheritance of degrees of broodiness is being continued as well as a study of the relation of broodiness to other characters affecting fecundity.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn.) The mean annual egg production of the last generation of this experiment was 221 eggs. The mortality rate in the laying houses was 34 per cent without culling and with all sisters of the families included. This flock was superior for intensity, but there was a greater percentage of broody birds than in the previous flock.

Egg size is being increased without the loss of high fecundity but more slowly than would be necessary if high intensity were given less consideration. Hatching records for 1932 were unsatisfactory because of a defective incubator.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been prepared and published as follows: "Early and late feathering in Rhode Island Reds," *American Naturalist* 66: 286-287, 1932; "Types of intensity in Rhode Island Reds," Bulletin 286; "The relation of feather pigmentation to intensity of laying in Rhode Island Reds," Bulletin 288; "Hereditary and environmental factors affecting variability in egg production," Bulletin 289; "Relation between body weight and age at sexual maturity in Rhode Island Reds," *Poultry Science* 12:23-25, 1933; and "Relation of weight at sexual maturity to annual egg production," *Poultry Science* 12:25-26, 1933.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) The third generation of crosses between exhibition and production-bred Rhode Island Reds is now being carried in the laying houses. The F_1 generation was intermediate in plumage color, yet showed a rather wide range of color. The mean annual egg record of this generation was 191.

The F_2 generation exhibited the extreme range in color of the parent stock. The mean annual egg record of these birds was about 157.

The F_3 generation came from mating $F_2 \times F_2$ and from mating F_2 to parental stock. There is very definite segregation both of color pattern and of fecundity traits.

Determination of Genetic Laws Governing Results of Inbreeding. (F. A. Hays.) The first generation of daughters hatched in 1929 from sire on daughter matings averaged 180 eggs with a mean age at first egg of 216 days. The second generation from half-brother x sister matings had an average annual egg record of 190 with a mean age at sexual maturity of 192 days. A third generation of 24 birds hatched in 1931 had a mean annual production of 196 eggs and a mean age at first egg of 213 days. None of the third generation daughters in one of the three inbred lines could meet the standard for breeders and this line became extinct with this generation.

The value of inbred males mated to unrelated females to test prepotency is now being studied.

Factors Affecting Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays.) The fifth generation of birds was hatched in 1932. The criterion

for selecting pullet breeders to produce this last generation was the ability to lay 52-gram, 57-gram and 59-gram eggs during the month of November. Previously these egg weights applied for the month of December. The daughters in these three lines are mated to three full brothers of distantly related stock each year. Egg size is being increased in all three lines but at a very slow rate in the 52-gram group.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Elimination Law. (H. Van Roekel, K. L. Bullis, O. S. Flint, and Miriam K. Clarke.) During the 1931-32 pullorum disease testing season, 420,861 blood samples were tested by the macroscopic tube agglutination method. This number represented 377,191 chickens in 455 flocks. Among the samples tested, 0.90 per cent were positive. This is the lowest percentage of positive tests ever attained in this State. No positive tests were recorded in two counties. In six other counties there were less than 1 per cent of positive tests. The number of non-reacting flocks was increased to 355. Of these, 180 flocks, representing 157,516 birds, were 100 per cent tested. No reactors were detected among 1,034 birds other than chickens. These birds were distributed among 25 flocks. Chickens were tested on 19 of these premises, and reactors were found in five of the chicken flocks. Necropsies were performed on 117 birds for 61 flock owners. The necropsy service has been found valuable in determining the pullorum disease status of a flock in which only doubtful reactors are detected.

Pullorum Disease Investigations. (H. Van Roekel, K. L. Bullis, O. S. Flint, and Miriam K. Clarke.) Results of recent investigations concerning jellied blood samples, susceptibility of pheasants and guinea fowl, agglutinins in young chicks, avenues of infection, a comparison of diagnostic tests, and the most efficient use of the agglutination test in eradication are reported in Control Bulletin 63.

Laboratory Service - Pathology. (G. L. Dunlap and K. L. Bullis.) During the year, 1,042 specimens were examined for 263 people, of whom 96 made personal calls at the laboratory. The specimens were distributed as follows: — 1,013 chickens, 3 pigeons, 8 guinea pigs, 4 swine, 6 rabbits, 2 turkeys, 2 ducks, 1 calf, and 1 mink. The diseases encountered most frequently were pullorum disease, rachitis, so-called "range paralysis", parasitism, and tumors. Tuberculosis was diagnosed in one turkey and in one hen.

Farm and Station Bang Disease. In assisting this project, the laboratory tested 1,371 blood samples by the tube agglutination method.

Infectious Laryngotracheitis. (C. S. Gibbs.) The studies on chronic carriers of infectious laryngotracheitis have been completed, and 22 chronic carriers have been found in approximately 1,000 birds examined by intratracheal swabs. The length of time virus was eliminated by these carriers varied from 37 to 741 days.

Immunity studies have been continued through the year. It has been determined that immunity to infectious laryngotracheitis is acquired by direct contact with the causative agent and is not transmitted to the offspring, except in rare instances where the hens have laid eggs for hatching while passing through the acute stages of the disease. Also it has been found that infectious laryngotracheitis is primarily a disease of pullets and cockerels, older birds being more or less immune to it. This natural resistance should not be confused with artificial immunity.

Several methods of vaccinating pullets and cockerels against infectious laryngotracheitis have been studied, and the bursa of Fabricius appears to be the most satisfactory site for inoculating birds with attenuated viruses. The immunity produced by vaccination in the bursa of Fabricius is not lasting in all cases unless a standard vaccine is used. As yet no simple, inexpensive process for standardizing the vaccine for infectious laryngotracheitis has been discovered, and for this reason no practical method for vaccinating birds on a large scale is recommended.

Four spraying solutions recommended for infectious laryngotracheitis have been tried out in the laboratory to determine their pharmacological action upon the respiratory system. These sprays were not found specific for infectious laryngotracheitis, since they did not destroy the virus in the tracheas of acute cases and chronic carriers.

A plan for the eradication and control of infectious laryngotracheitis has been worked out by laboratory studies and field tests and is recommended until a more satisfactory way of handling the disease is discovered. The plan follows:

The Massachusetts Plan for the Eradication and Control of Infectious Laryngotracheitis

1. All birds on the premises that have had infectious laryngotracheitis or been exposed to it should be condemned and disposed of at the end of the hatching season or at any other time most convenient to the owner for the expedient eradication of the disease.

2. Incubators and brooders should be cleaned, disinfected, and isolated some distance from the condemned birds.

3. Chicks that have not been exposed to infectious laryngotracheitis may be kept for restocking, provided they are entirely separate from the condemned birds and the premises occupied by them.

4. All buildings occupied by the condemned birds should be thoroughly cleaned and disinfected as soon as possible after they are vacated.

5. The houses and yards after cleaning and disinfecting should be opened to the air and sunshine and left vacant for two months or longer.

6. Overalls and shoes worn around the condemned birds or on the premises occupied by them should not be used in the houses, on the range, handling feed, or in caring for chicks for re-stocking, unless laundered or thoroughly disinfected.

7. Utensils and equipment used around the condemned birds or in cleaning and disinfecting the premises occupied by them should not be used in the houses or on the range where the chicks for re-stocking are kept unless said utensils and equipment have been thoroughly cleaned and disinfected.

8. Permitted Disinfectants should be used as directed for disinfecting all poultry houses, utensils, and equipment.

9. New stock should be introduced only from absolutely clean flocks or from the poultrymen's own hatchings which have been adequately protected from infection.

10. The subsequent re-introduction of infectious laryngotracheitis should be carefully guarded against.

Twenty-seven poultrymen are known to have tried the plan as recommended or some modification of it. Twenty-three of them succeeded in eradicating the disease completely and four failed. The four failures were found to be due either to improper cleaning and disinfection, or to the lack of sufficient airing and sunning of the house and yards.

Infectious Bronchitis. (C. S. Gibbs.) An epizootic of infectious bronchitis, due to a streptococcus, has been found affecting a flock of hens and roosters. The

causative agent was isolated from the bronchial tubes and tracheas of infected birds by means of blood agar plates, and transmitted in series to susceptible fowls and roosters, and successfully recovered from each case.

Culturally, morphologically, and serologically the streptococcus resembles the microorganism isolated from a similar condition in baby chicks reported in Bulletin 280, p. 242, 1932, except that the former organism affected adult birds and the latter was found only in baby chicks. Laboratory studies indicated that this was an instance of biological adaptation which could be changed at will.

The microorganism isolated in these epizootics is a haemoglobinophilic streptococcus and is responsible for a condition which has been called infectious bronchitis. The prevalence of this disease in the poultry population at large has not been determined. However, laboratory studies indicate that the mortality and loss in egg production may not be as serious as in infectious laryngotracheitis.

Avian Paralysis or Neurolymphomatosis. (C. S. Gibbs.) Pathological studies of avian paralysis have been continued through the year, and perivascular infiltration of round cells in the capillaries carrying blood and lymph to the nerves has been observed in incipient stages of the disease. Also metastatic infection of nerves from sarcomas in splanchnic tissue, by means of round cells conveyed in the blood and lymph vessels, has been evident in selected cases. A comparative pathological study of neurolymphomatosis and lymphatic leukemia has been undertaken. Up to the present it has not been possible to differentiate the hyperplastic tissues in lymphatic leukemia from certain forms of lymphoblastoma, although neurolymphomatosis may be readily differentiated from both on the basis of blood counts, differential blood stains, and gross pathology.

Cases of neurolymphomatosis from flocks in which the disease has been introduced comparatively recently show more inflammation and generalized lesions than those from flocks in which the disease has existed for a number of years.

WALTHAM FIELD STATION
(Waltham, Massachusetts)
Ray M. Koon in Charge

The research of this Station has been projected principally along the same lines as in 1931. As rapidly as conclusive results on any phase of a project have been obtained, they have been released to the commercial growers for application to their problems, without waiting until the completion of the entire project. For reports on experiments conducted at this Station, in addition to those listed under this caption, see reports of the Departments of Botany, Entomology, Floriculture, and Olericulture.

An increase of 50 per cent in the total number of visitors to the Field Station was recorded in 1932 over the year previous. During the year 2446 persons came to the Station for personal conferences with members of the staff regarding troubles threatening their commercial enterprises, or in quest of assistance with problems relating to amateur horticulture as it is practiced about the home. Telephone inquiries have numbered 2114; and 2748 letters (not circular) and over 2000 bulletins, leaflets, and mimeographs have gone out in answer to requests for information.

In March a two-day course offered to commercial flower producers and retail florists was attended by 225. A school for home gardeners, conducted for two days last April, was attended by 800 persons from 54 cities and towns in the eastern part of the State and several cities in Maine, New Hampshire, and Rhode Island.

The Boston Market Gardeners Association has continued to use the Field Station as headquarters for their monthly executive committee meetings.

The annual Field Day was held on August 3 with 888 farmers attending.

The Plant House. (P. W. Dempsey.) Interest in the plant house is increasing. Growers of both ornamental and vegetable plants are finding it of much value, and many amateur gardeners are also finding this type of structure economical to build and operate, and derive considerable pleasure from their winter garden. A new up-to-date plant house was built during the fall according to our latest plans, and an effort is being made to interest commercial concerns to standardize all the parts of the structure they sell.

Growers who have lost their source of heat (fresh manure) are now interested in installing hot water heating systems in their frames. The plant house offers such superior conditions for growing seedlings that the grower is advised to construct a plant house and use his frames to increase his capacity.

Electricity as a Source of Heat in the Hotbed and Propagating Bench. (P. W. Dempsey.) Work on this project was continued in both the greenhouse and hotbed. Interest on the part of growers is bound to increase as they become acquainted with this mild, controlled source of heat. Improvements in methods of use and type of equipment are constantly being made. Commercial growers in several states have installed rather extensive outfits.

From the results of this work it is recommended that growers go slowly in making an investment in installation and equipment, a trial bed or bench of from 4 to 10 sash being suggested. Operating costs at a current rate of 3 cents per kilowatt hour have been rather high. The cost of maintaining the temperature of a propagating bench (sand) 3 feet wide and 5 inches deep at 60° F. with the air temperature 50° F. was one cent for each running foot each 24 hours. Cost of the hotbed was $1.60 per sash for the season March 10 to May 20, with the minimum temperature 45° F. Hot water has proved as satisfactory and much lower in operating cost -- 50 cents per sash. Work will be continued to gain more essential knowledge of advantage to the grower.

Vegetable Variety Trials. (P. W. Dempsey.) Over fifty strains of sweet corn were planted on two different dates. The outstanding feature in this year's trials was the number of new strains of Early Golden Market, introduced some seven years ago by Gill Brothers of Portland, Oregon, appearing under different names -- Early Sensation, Yellow Sensation, Extra Early Yellow, Golden Hummer, Extra Early Golden, and others. These strains are certain to become popular since they all mature before Bantam and bear a large ear of Bantam quality. Golden Sunshine is but little different in general characteristics and is constantly gaining in popularity. In later-maturing varieties there is considerable interest in "Top-Crossed" and "Inbred" strains of sweet corn. The strains mature a heavy crop of excellent-quality ears of even size, and are of particular value for the cannery.

Forty-four strains and varieties of beets were seeded in two plantings. More attention is being paid to inside color of the root than formerly. Ohio Canner is a variety showing promise for a particular trade. It is rather small in size, of excellent quality, very dark in color, and matures evenly.

Eighty strains and varieties of tomatoes were planted, half of the plants of each strain being staked and half grown flat. The new variety, Pritchard, introduced by the United States Department of Agriculture, did not show up as well as ex-

pected. Seventy-five per cent of the staked plants of this variety were determinate, some producing only one cluster of fruit, and others ranging from two to four clusters. Grown flat, the growth was normal. Fruit was of good size and quality, but a large proportion showed an objectionable yellow under-color similar to that of Break O'Day. There is always much interest in our tomato trials on the part of all growers who visit the Field Station. Peculiar as it may seem, there is no variety which is outstanding year after year; therefore, it is difficult to make definite variety or strain recommendations to growers. Seasonal conditions affect the growth of tomatoes considerably.

Beans were included in the trials this year on account of the many new variety names found in the seed catalogues. There is a distinct trend in popularity toward the more extensive use of the round-podded varieties. Although the flat podded varieties Bountiful (green pod) and Sure Crop (wax) are still the most popular, there is more interest than ever in Pencil Pod Wax and the new round pod varieties Tendergreen and Stringless Black Valentine.

Twenty celery varieties made an exceptionally good growth in spite of the abnormally dry season. New variety names appearing this year in our trials were Golden Phenomenal, Golden Detroit, Utah Golden Crisp, Salt Lake, and Florida Queen. It will be necessary to try all of these again before final judgment is passed. Up to date, there is no reason for recommending that our growers make any change from the varieties they are now growing -- Pascal for winter and Golden Plume or Wonderful for summer and fall.

New names appearing on the variety lists of carrots also made it imperative to conduct a carrot variety test this year. Perfection, Pride of Denmark, and Imperator are very similar in type to the Coreless although much larger. All are uneven in size and type. Both favorable and unfavorable comments have been received from growers on all these varieties, so it is recommended that a grower determine just how each one performs under his conditions before planting any quantity. The new Red Cored Chantenay is certainly a big improvement in quality and the type is exceptionally uniform. Tendersweet, apparently a strain of Red Intermediate, is a carrot of exceptional quality and similar in color to the Red Cored Chantenay. Many local market gardeners are now using the Hutchinson variety for bunching, in place of the Chantenay and Danvers varieties formerly used for this purpose.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station. H. F. Bergman, Senior Pathologist, U.S.D.A., in Charge.

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman, W. E. Truran, and Jos. L. Kelley.) Reciprocal crosses between Early Blacks and McFarlins were made in July 1932. The crosses of Early Black by McFarlin were unsuccessful. The reciprocal cross of McFarlin by Early Black yielded a considerable number of fruits which matured normally. In order to determine the possible existence of resistant strains within single varieties, a number of flowers of the varieties Early Black, McFarlin, and Howes were self-pollinated. No fruits were obtained from selfed flowers of Early Black, but fruits were obtained from both the other varieties.

During September some fifty selections of wild cranberries were made in Maine. These selected wild vines were taken to East Wareham where they are being held over winter to be propagated in 1933. Several of the selected wild vines show very desirable vine and fruit characteristics.

Oxygen Content of Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman and W. E. Truran.) Some experiments to determine the effect of absence of oxygen in winter-flooding water on the development of terminal and fruiting buds during the following growing season failed because of unfavorable weather conditions. Several hundred buds of Early Blacks and Howes on the State Bog were tagged and their development was followed through the season. Large terminal buds tended to produce more fruits than either medium or small terminal buds. This tendency was more evident in Howes than in Early Blacks.

Regeneration of False Blossom Bogs. (H. F. Bergman and Jos. L. Kelley.) In cooperation with growers, two areas of bog badly infested with false blossom were sprayed in July with commercial weed killer (probably sodium arsenite) diluted 1:30 and applied at the rate of 600 to 800 gallons per acre. This treatment appears to be very satisfactory.

June Flooding for Fireworm Control. (H. F. Bergman, W. E. Truran, and Jos. L. Kelley.) Severe injury to flower buds and growing tips, due to low oxygen content in the flooding water, was observed in one bog during the flooding period for fireworm control. The lowest oxygen content found was 1.9 cc. per liter. Fireworms were apparently completely killed. No injury was observed on two other bogs. From experiments it appears that fireworms can be killed by submergence for 12 hours in water at a temperature of 15° to 20° C., and an oxygen content of less than 4 cc. per liter. An oxygen content of less than 1.0 cc. per liter for 5 to 6 hours causes injury to flower buds and growing tips.

June Flooding for Leafhopper Control. (H. F. Bergman and W. E. Truran.) Flooding for 16 to 18 hours killed about 75 per cent of the leafhoppers on one bog. The oxygen content of the water did not fall below 3.5 cc. per liter. No bud injury was observed. Flooding for 12 to 15 hours, on another bog, killed only about 50 per cent of the leafhoppers. The lowest oxygen values here were 3.5 to 4.0 cc. per liter.

Investigations on the Effect of Copper Residues from Bordeaux Spray on the Growth of Cranberry Vines. (H. F. Bergman and W. E. Truran.) The greatest amount of copper, which varies from 150 to 200 milligrams per kilogram of dry soil, is found in heavily sprayed bogs with a peat substratum. There is much less copper in soils of very wet bogs and of those with a sand substratum. The amount of copper in vines varies from 50 to 100 milligrams per kilogram of dry vines. The leaves ordinarily contain one and one-half to two times as much copper as the stems, for the same weight of material. In one experiment copper sulfate was applied directly to the soil in amounts equivalent to 800, 1200, 1600, and 2400 pounds per acre, without injury to the vines and with no apparent reduction in yield.

Spraying Experiments with Bordeaux and Organic Mercurial Sprays. (H. F. Bergman, W. E. Truran, and Jos. L. Kelley.) Spray plots were located on four separate bogs. Bordeaux made up by the 4-4-50 formula, with chemically hydrated lime, and applied at the rate of 350 to 400 gallons per acre was used on all bogs. Two organic mercurial sprays were used on one bog. The reduction

in the amount of rot showed a direct relation to the number of applications of the spray. The two mercurial sprays used gave as good control of fungous rots as the Bordeaux.

Storage Test of Cranberries. (H. F. Bergman, W. E. Truran, and Jos. L. Kelley.) Berries were stored in the basement of the State Bog building, at air temperature, which on November 1 was about 15° C., and later dropped to about 5° C. Cranberries from sprayed plots showed less loss from fungous rots than those from unsprayed plots. In the berries from two of the bogs this difference did not become apparent until about January.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station.

C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger.) In continuation experiments numerous strains of Havana Seed tobacco were grown in the field during 1931 in a further attempt to find strains that will be satisfactory under Connecticut Valley conditions for resistance to black root-rot, type of plant, type and quality of leaf, and producing capacity. One strain was Havana Seed of the sort that is grown more commonly in the Connecticut Valley, known to be susceptible to black root-rot, but acceptable for type of plant and type and quality of leaf. This strain was used as a standard of comparison for types. One strain was Havana Seed 142A3, known to be satisfactorily resistant to black root-rot, and was used as a standard of comparison for resistance. Of the new strains being tested, eight had been grown in 1930, and seven were grown for the first time in 1931. These strains were all grown on land which in one case was free or nearly free of *Thielavia basicola*, and in another case was heavily infested with *Thielavia basicola*. Of the fifteen new strains tested in 1931 under these circumstances, eight were selected as apparently deserving further testing.

The production of these eight strains when grown on soil free or nearly free of *Thielavia basicola*, was as follows:

		Yields per Acre - lbs.	Grade Index	Crop Index
Havana Seed - Common strain		1868	.431	805.
Havana Seed 142A3		1828	.436	797.
Havana Seed - new strains	⁂ 5	2106	.474	998.
	⁂ 13	1946	.475	924.
	⁂ 14	1901	.482	916.
	⁂ 9	1897	.480	911.
	⁂ 22	1922	.460	884.
	⁂ 10	1807	.478	864.
	⁂ 23	1899	.445	845.
	⁂ 15	1818	.452	822.

The production of these same eight strains when grown on soil heavily infested with *Thielavia basicola*, with each strain having its own check of common Havana grown in adjacent rows, was as follows:

		Yields per Acre - lbs.	Grade Index	Crop Index
Havana Seed 142A3		2189	.470	1029.
Common Havana (check)		1237	.314	388.
Havana Seed - new strains	#5	2298	.470	1030.
	check	1315	.320	421.
	#13	2523	.459	1163.
	check	1415	.350	495.
	#14	2315	.430	995.
	check	1421	.340	483.
	#9	1925	.388	747.
	check	1285	.312	401.
	#22	1892	.341	645.
	check	1014	.277	281.
	#10	2023	.387	783.
	check	1364	.313	427.
	#23	2109	.411	867.
	check	1126	.290	327.
	#15	1895	.407	771.
	check	1410	.309	436.

Some of these newer strains deserve testing on a considerably larger scale in numerous places in the Connecticut Valley to determine their excellence in practical production.

Note: Grade Index is a number expressing the grading of all the tobacco produced by a strain in an experiment. It is based upon the percentage of grades, and the relative percentage values of these different grades, as given below:

Light wrappers	1.00	Long darks (19″ & longer)	.30
Medium wrappers	.60	Dark stemming (17″ & shorter)	.20
Long seconds (19″ & longer)	.60	Fillers	.10
Short seconds (17″ & shorter)	.30	Brokes	.10

Grade index is derived by multiplying the percentage yield of each grade by its respective price in the above schedule, adding the products, and dividing by 100.

Crop index is a number expressing crop value and is derived by multiplying the total acre production of tobacco in pounds by the grade index value of that particular tobacco.

Grade index and crop index and the adopted price relationships given above do not necessarily represent commercial values and prices.

PUBLICATIONS

Bulletins

280 Annual Report for the Fiscal Year Ending November 30, 1931. 64 pp. February, 1932.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

281 Experiments with Permanent Pastures. A. B. Beaumont. 36 pp. illus. April, 1932.

A large proportion of the farm land of Massachusetts consists of stony uplands more suitable for permanent pastures than for tilled crops. The improvement of pastures by top-dressing with fertilizers offers attractive possibilities; and the fact that large areas have already reverted to forest shows what must happen to existing pastures if fertilizer is not applied, or if the price of milk is too low to make such application profitable. A pasture which is weedy or run-down because of a lack of plant food can be brought back to productive condition only by the use of plant food. On the basis of the experiments reported, it is recommended that 1 ton of ground limestone (or its equivalent in hydrated lime) be applied every 6 years; 480 pounds of 16 per cent superphosphate and 160 pounds of muriate of potash, every 3 years; and 160 pounds of nitrate of soda, annually. At prices prevailing early in 1932, this treatment can be made by an annual investment of $5 to $10 an acre and it is believed will yield a fair return under Massachusetts conditions.

282 Relation Between Egg Quality and Price. Adrian H. Lindsey and Hubert W. Yount. 22 pp. May, 1932.

In order that the poultryman may feel justified in placing special emphasis on the quality of eggs and secure in making the extra expenditure involved in producing a higher grade product, he should have some assurance that quality values are recognized by the consumer. The most definite and significant relationship discovered from this analysis is that prices are directly related to weight under all conditions. That weight is a significant factor is not new, but it has not been known that weight is more important at one season of the year than another and that the premiums which are paid for weight are fairly definite. If premiums are known, it will be possible to determine by further research whether the production of large eggs is profitable.

283 Downy Mildew of Cucumbers. William L. Doran. 22 pp. May, 1932.

Downy mildew is a common and important disease of cucumbers in Massachusetts as well as in most of the eastern and southern states. The investigation included the source of primary infection, the effect of climatic factors, and the prevention of infection by the use of fungicides. All available evidence indicates that the fungus probably reaches Massachusetts from states farther south after a gradual northern movement by the aid of wind. Two to three hours on a leaf wet with rain or dew is enough for the germination of most of the conidia of this fungus, and five hours is sufficient to produce infection of leaves. In both field and greenhouse, copper fungicides are to be preferred to sulfur for the control of downy mildew. In Massachusetts the first application of a copper fungicide should be made, in the field, about July 25, and later applications should be made at weekly intervals. Bordeaux mixture 3:3:50 is a sufficient concentration for use in the field. Bordeaux 1:1:50 prevented infection of greenhouse cucumbers, and this is the concentration recommended for use in greenhouses.

284 Questions and Answers Concerning Pullorum Disease. H. Van Roekel. 23 pp. illus. May, 1932.

The purpose of this bulletin is to make available for the Massachusetts poultry industry information which will aid the poultrymen to improve their methods of establishing and maintaining pullorum disease-free flocks. The subjects covered are history and distribution of the disease, its nature and dissemination, control and eradication, including sanitary measures recommended.

285 The Relation of Temperature to the Activity and Control of the Plum Curculio in Apples. W. D. Whitcomb. 16 pp. illus. June, 1932.

The plum curculio frequently does more damage to apples in Massachusetts than all other insects together. As a result of the heavy loss to fruit growers, studies of the factors which influence the activity of this insect were conducted at Waltham. Early in the work temperature was found to play an important part in the problem of control, and the more recent studies have centered around this factor. Recommendations for Massachusetts, based on these studies, are: After the blossom petals have fallen, apply a special spray or dust in the first period of warm weather when the maximum temperature reaches 75° F. or higher and such temperatures promise to continue for 2 or more successive days. Use 4 or 5 pounds of lead arsenate in 100 gallons of spray, preferably with the addition of 1 pint of fish oil or linseed oil as a spreader or sticker. Except in severe infestations, 85-15 sulfur-lead arsenate dust can be substituted for the spray. When there are two distinct periods of high temperature within 15 days after the proper time for the calyx spray, apply a spray or dust in each period, using the same materials, and determining the time of application by the same temperature requirements as before. On scab susceptible varieties, or where the addition of a fungicide is desirable for any reason, liquid lime-sulfur or a similar material can

be added to the spray without danger of greatly decreasing the efficiency of the mixture for combating the plum curculio.

286 Types of Intensity in Rhode Island Reds. F. A. Hays and Ruby Sanborn. 11 pp. June, 1932.

Intensity or rate of laying is one of the very important inherited characters affecting annual egg production in poultry. Various methods have been used for measuring intensity, and there is an increasing need for more information concerning the relative merits of the different measures as well as for definite data concerning the relation of intensity to other traits affecting fecundity. Interrelations between the rate of laying in three different seasons and the relative values of six short-time measures of intensity are considered in this report. It was found that the most significant short-time measure of intensity is spring clutch size, but no short-time measure of intensity is as accurate as the mean clutch size for the entire year.

287 Frozen Fruits and Their Utilization in Frozen Dairy Products. M. J. Mack and C. R. Fellers. 28 pp. illus. July, 1932.

The frozen-pack method is used annually to preserve large quantities of fruit, much of which is later used for flavoring ice cream. Fruits used for this purpose have a very pronounced influence on the quality of the final product, but very little is known regarding the most satisfactory ways of processing fruit for utilization in frozen dairy products. The plan of the investigation was to prepare experimental packs of the fruits in one-gallon cans, freeze these under known conditions, store for approximately one year, thaw, examine carefully, and finally use the fruit in the manufacture of fruit ice creams, sherbets, and ices. The greater part of the study was with strawberries, but raspberries, peaches, cherries, and a few other varieties of minor importance were included.

288 The Relation of Feather Pigmentation to Intensity of Laying in Rhode Island Reds. F. A. Hays. 8 pp. October, 1932.

Deep rich plumage color and high winter laying intensity in Rhode Island Reds are desirable characters which can be influenced by breeding. This investigation was undertaken to determine to what extent both of these characters can be developed simultaneously by the breeder. It would seem to be a laborious process to establish uniform deep pigmentation and high intensity in a flock, but a medium shade of red should be maintained without difficulty.

289 Hereditary and Environmental Factors Affecting Variability in Egg Production. F. A. Hays. 12 pp. illus. December, 1932.

It is a well-known fact that both hereditary and environmental factors affect the number of eggs laid by a hen. Evidence is not conclusive on many points, however, and experimental data have not been reported to furnish information concerning the quantitative variation of specific fecundity traits from generation to generation. There is at present an outstanding need of a clear-cut distinction between the effects on fecundity of heritage and environment. Such a problem offers many difficulties, the most outstanding of which is the lack of any measure of fecundity in males. This report concerns itself with results obtained in carrying three lines of birds through four generations. Consideration is given to variability in five inherited fecundity characters: sexual maturity, intensity, winter pause duration, total days broody, and persistency. Variability in winter and annual egg records is also recorded. Such environmental influences as hatching date, increase or decrease in body weight, and daily house temperature are considered in relation to egg production and the relative importance of each is discussed.

290 The Story of Field A of the Massachusetts Agricultural Experiment Station: A Review of Experiments with Nitrogen Fertilizers. Fred W. Morse. 23 pp. illus. November, 1932.

The year 1932 marks the fiftieth anniversary of the formal organization of agricultural research at Massachusetts State College. It was in November, 1882, that the Experiment Station was established, and field plot experiments begun the next year represent some of the first activities. It seems fitting, therefore, after this fifty-year period, that results from this work be compiled and recorded in permanent form. Field A was laid out in 1883 on "run out" hay land and included eleven plots of one-tenth acre each. Seven successive crops of corn were grown from 1883 to 1889, to study the effects of different forms and kinds of plant food The earlier harvests showed potash to be the most needed fertilizer; the later ones indicated that a complete fertilizer had become necessary. Four standard types of nitrogen fertilizers -- nitrate of soda, sulfate of ammonia, dried blood or fish or cyanamid, and stable manure -- were compared in 1889, and the comparison was continued with minor

changes until 1921. A variety of crops was grown, and tables show results obtained with oats, soy beans, potatoes, hay, corn, and miscellaneous crops. The value of Field A to agriculture is its history of the diversity of results. Back of any subsequent work upon it are authentic records of each plot, of which no similar records were to be had when the field was laid out.

291 Two Systems of Feeding Dairy Cows: High Roughage and Low Grain versus Low Roughage and High Grain. J. B. Lindsey and J. G. Archibald. 15 pp. December, 1932.

The amount of grain to be fed to cows is a question of perennial interest to farmers, particularly in a state like Massachusetts where grain is bought outright, while roughage is grown at home. Though much has been written on the subject, it has been largely opinion unsupported by experimental evidence. This bulletin reports the results of a long-time experiment (October 1, 1928 to March 31, 1932) conducted at this station. Viewing the results as a whole, the low roughage group of cows had a rather better record. They looked thriftier, put on more flesh, milked more freely, maintained their production better from year to year, maintained their average test better, and were more nearly mormal in their reproductive function. It was evident that cows will not produce to the limit of their ability on a high roughage system of feeding. Which method of feeding will produce milk more economically, however, depends very largely on local conditions as to production and markets, and in a large measure is a problem to be solved by the individual farmer.

292 Carbon Disulfide Emulsion for the Control of the Root-Knot Nematode. E. F. Guba. 16 pp. illus. December, 1932.

Many greenhouse establishments lack the necessary means for sterilizing soil with steam or hot water. Even where these methods are practiced with successful results, they are laborious and slow and require expensive equipment. Experiments have been conducted which show that the use of carbon disulfide emulsion as a soil drench in greenhouses can be relied upon to greatly reduce the root-knot nematode as a factor causing crop loss, at a cost of approximately $0.009 per square foot for chemicals. Carbon disulfide emulsion is compatible with formaldehyde. A stock emulsion containing 68 per cent carbon disulfide, 26 per cent water, and 6 per cent rosin-fish-oil soap in a 1:50 concentration for controlling the root-knot nematode, with the addition of 2/3 gallon of formaldehyde if soil-inhabiting fungi are a factor, is effective. The addition of formaldehyde adds about $0.007 per square foot to the cost of the treatment.

Control Bulletins

62 Seed Inspection. F. A. McLaughlin and Margaret E. Nagle. 47 pp. February, 1932.

63 Twelfth Annual Report on Eradication of Pullorum Disease in Massachusetts. H. Van Roekel, K. L. Bullis, O. S. Flint and Miriam K. Clarke. 80 pp. September, 1932.

64 Inspection of Commercial Feedstuffs. Philip H. Smith. 48 pp. September, 1932.

65 Inspection of Commercial Fertilizers. H. D. Haskins. 50 pp. October, 1932.

66 Inspection of Agricultural Lime Products. H. D. Haskins. 8 pp. December, 1932.

Meteorological Reports

517 - 528, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. C. I. Gunness. 4 pp. each.

Reports of Investigation in Journals

(Numbered Contributions)

121 Putting First Things First in Agronomy. F. J. Sievers. Jour. Amer. Soc. Agron. 24:29-32. January, 1932.

122 The Effect of Environment on the Nematode of the Tomato Gall. Linus H. Jones. Jour. Agr. Research 44:275-285. February 1, 1932.

125 An Ataxia of Chicks Associated with Nephritis. Glen L. Dunlap. Jour. Amer. Vet. Med. Assoc. 80 (N. S. 33): 880-885. June, 1932.

126 Acetic Acid and Pyroligneous Acid as Soil Disinfectants. William L. Doran. Jour. Agr. Research 44:571-578. April 1, 1932.

127 Stomatal Apparatus of the Cultivated Cranberry, *Vaccinium Macrocarpon*. Wm. H. Sawyer, Jr. Amer. Jour. Bot. 19:508-513. June, 1932.

128 A New Jelly-Strength Tester. C. R. Fellers and J. A. Clague. Indus. and Engin. Chem., Analyt. Ed. 4:106. January 15, 1932.

129 The Significance of Differences in Means in Repetition Experiments. F. A. Hays. Poul. Sci. 11:14-17. January, 1932.

130 A Three-Year Study of the Chemical Composition of Grass from Plots Fertilized and Grazed Intensively. J. G. Archibald, P. R. Nelson and E. Bennett. Jour. Agr. Research 45:627-640. November 15, 1932.

131 Susceptibility of Chickens to Brucelliasis. H. Van Roekel and others. Jour. Amer. Vet. Med. Assoc. 80 (N. S. 33): 641-642. April, 1932.

132 The Mineral Composition of Dates. M. M. Cleveland and C. R. Fellers. Indus. and Engin. Chem., Analyt. Ed. 4:267. July 15, 1932.

133 Rapid Centrifugal Method for Pectic Acid Determination. C. R. Fellers and C. C. Rice. Indus. and Engin. Chem., Analyt. Ed. 4:268. July 15, 1932.

134 The Influence of Temperature on the Nitrate Content of Soil in the Presence of Decomposing Cellulose. James E. Fuller and Linus H. Jones. Soil Sci. 34:337-350. November, 1932.

135 Early and Late Feathering in Rhode Island Reds. F. A. Hays. Amer. Nat. 66:286-287. May-June, 1932.

136 Public Health Aspects of Frozen Foods. Carl R. Fellers. Amer. Jour. Pub. Health 22:601-611. June, 1932.

137 Monograph of the Genus Pestalotia, Part II. E. F. Guba. Mycologia 24: 355-397. July-August, 1932.

139 Chronic Carriers of Infectious Laryngotracheitis. Charles S. Gibbs. Jour. Amer. Vet. Med. Assoc. 81: (N. S. 34): 651-654. November, 1932.

144 Vitamin C in Canned Citrus Products. Carl R. Fellers and Paul D. Isham. Jour. Home Econ. 24:827-832. September, 1932.

146 Recent Developments in Ice Cream Manufacture. M. J. Mack. Food Industries. August, 1932.

Other Contributions to Journals

(Unnumbered)

A Demonstration of Basal Growth. C. J. Gilgut and Linus H. Jones. Both Gaz. 94:221. September, 1932.

Twig Scab and Spray Injury. E. F. Guba. Mass. Fruit Growers' Assoc. Rpt. 38:149-153. 1932.

Forcing Gladiolus with the Aid of Artificial Light. Linus H. Jones. N. E. Gladiolus Soc. Yearbook 1932:123.

New Theories About Flower Pots. Linus H. Jones. Horticulture 10:50. February 1, 1932.

Aeration of Soil in Plant Containers. Linus H. Jones. Florists' Exch. 79 (11):39. March 12, 1932.

Why House Plants Die in Dry Modern Homes. Linus H. Jones. New York. Times. Sunday, Science, April 10, 1932:5.

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Cement Flower Pots. Linus H. Jones. Florists' Exch. 80 (2):9. July 9, 1932.

Summary of Orchard Pests in 1931. A. I. Bourne. Mass. Fruit Growers' Assoc. Rpt. 1932.

Control Studies of Apple Maggot in 1931. A. I. Bourne and W. H. Thies. Mass. Fruit Growers' Assoc. Rpt. 1932.

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Publication of this Document Approved by Commission on Administration and Finance. 2500-4-'33 No. 8018

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 294 JANUARY, 1933

Recreational and Forestry Uses of Land in Massachusetts

By David Rozman

During the last few decades there has been a considerable decline in the land area under cultivation in the State of Massachusetts, resulting in the presence of many idle acres in various agricultural communities. This study attempts to analyze the present condition of this abandoned farm land and to point out the place of recreational and forestry uses in developing a balanced program of land utilization for the Commonwealth.

MASSACHUSETTS STATE COLLEGE
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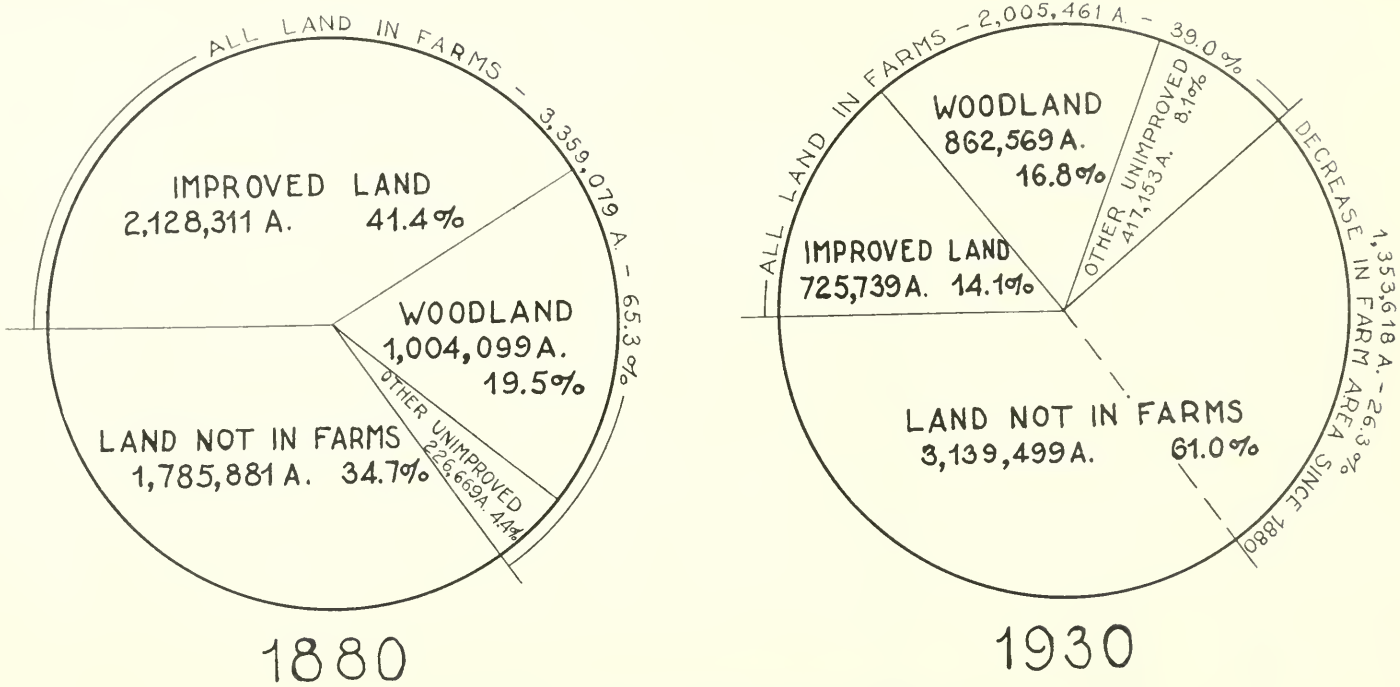

Chart 1. — Land Utilization in Massachusetts, 1880 and 1930.

RECREATIONAL AND FORESTRY USES OF LAND IN MASSACHUSETTS

By David Rozman, Assistant Research Professor of Agricultural Economics

INTRODUCTION

One of the most important developments facing Massachusetts is the rapidly changing conditions of land utilization shown by the decline in the amount of land in farms according to the Federal Census. The withdrawal from farming of large land areas creates in different agricultural communities a set of problems which can not be fully understood or dealt with without better information and analysis of the effect produced by new trends in land utilization. The study[1] of part-time farming brought out the fact that much of the land in the State previously held by regular farmers is now operated by part-time farmers. Further indications are that much of the land withdrawn from agriculture is being devoted to recreational and forestry uses. The latter begin to rise into greater and greater prominence in the general scheme of land utilization in the State. Considerable areas of forest land are being acquired by public and semi-public bodies, and land for recreational purposes, especially for playgrounds and summer homes, is being taken up by the people living in the cities.

With these factors in mind it is intended:

1. To trace the changes in agricultural land utilization during the last few decades.

2. To ascertain the new uses of land taken out of agriculture with a special consideration of land used for recreational and forestry purposes.

3. To analyze the effect of recreational and forestry uses of land on agriculture in Massachusetts towns.

4. To devise land policies consistent with both the interests of agriculture and the best methods of utilization of land resources in the State.

Changes in Farm Land Utilization in Massachusetts

According to the United States Census of Agriculture the total amount of farm land in Massachusetts has been steadily declining during the last few decades, registering a drop from 3,360,000 acres in 1880 to a little over 2,000,000 acres in 1930. (Chart 1) The loss of almost 1,360,000 acres during this 50-year period was accompanied by a decrease in the total number of farms from 35,406 to 25,599. (Chart 2) Of much greater significance, however, is the change in the improved acreage. Not only has the total amount of land in farms declined, but a great decline has taken place also in the amount of farm land under cultivation. The improved acreage on farms in 1930 was only 725,739 acres, or a little over one-third of what it was in 1880. At the present time there are in the State 118 towns, or about one-third of the total number, with less than 25 per cent of their total area in farms. In 62 towns the average value of farm land is below $25 per acre, and in 34 towns below $15 per acre. To this should be added the fact that 128 towns have less than 40 per cent of their farm area in improved land, and 54 towns less than 25 per cent.

[1] Rozman, D. Part-Time Farming in Massachusetts. Mass. Agr. Exp. Sta. Bul. 266. 1930.

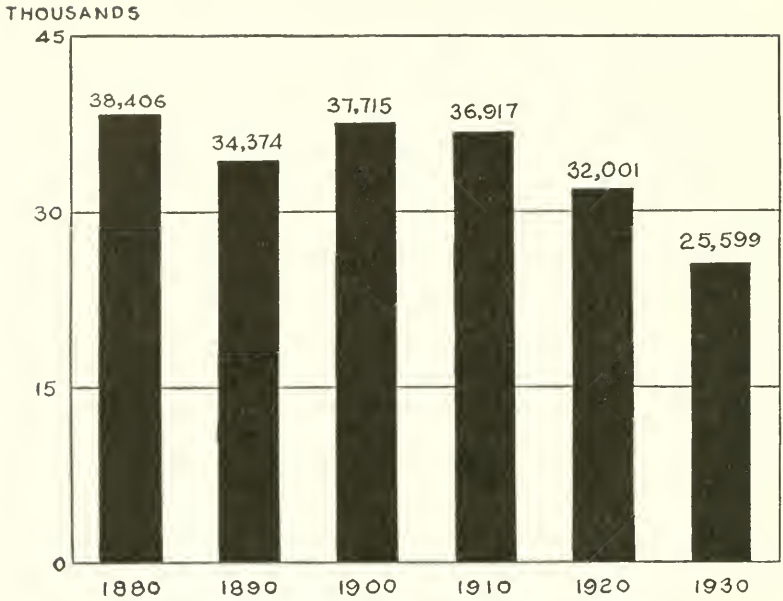

Chart 2. — Number of Farms in Massachusetts, 1880-1931.

Non-Resident Ownership

The immediate result of the withdrawal of this large acreage from farming is the ownership by non-residents of a considerable portion of land in many agricultural communities. To determine the amount of land so owned has been possible through the assessors' records, as Massachusetts towns are required by law to furnish to the commissioner of taxation every three years a complete record of landholdings with their valuation and taxes. From the information supplied by the assessors in 1928 a record was taken of the area, valuation and taxes on the land owned by non-residents in every fourth town, arranged alphabetically, with a population below 10,000. On this basis the data on resident and non-resident ownership were obtained for 71 towns, which, closely checked, proved to be a representative sample for all the towns in this group.

In a number of towns the general state of the utilization of land owned by non-residents and the significance of this land area for local agriculture was ascertained through personal interviews with town clerks, assessors, and other town people familiar with local conditions. In 5 towns situated in different sections of the State detailed information was obtained through the same means as to the utilization of every piece of land owned by non-residents.

In addition, with the cooperation of a real estate agency operating in Berkshire County, it was possible to obtain a record of changes in valuation and land utilization of 50 farms which have been sold since 1925. The analysis of the data on valuation of recreational property secured by the State Industrial Commission also proved to be helpful in ascertaining the significance of recreational development in the utilization of land resources.

TABLE 1. — PERCENTAGE OF TOWN ACREAGE IN NON-RESIDENT OWNERSHIP.

Town	Percentage of Non-Resident Ownership	Town	Percentage of Non-Resident Ownership
Bridgewater	12.5	Ashfield	26.6
Winchendon	15.4	Chatham	27.8
Gill	15.9	Dalton	29.4
Stoneham	16.6	Southampton	29.6
Millbury	16.7	Ipswich	29.9
Oak Bluffs	16.8	Hingham	30.2
Colrain	16.9	Norton	30.4
Concord	16.9	Montgomery	31.1
Dudley	17.5	Ashland	31.8
Templeton	17.6	Boxboro	31.8
Westboro	18.0	Lancaster	33.2
Townsend	18.5	Chester	34.9
Spencer	18.7	Middlefield	35.2
Merrimac	20.2	Ashburnham	36.3
Harvard	20.3	Rutland	37.0
Seekonk	20.5	Essex	37.6
E. Bridgewater	21.0	Scituate	37.8
Lincoln	21.1	Alford	39.3
Canton	21.7	Cummington	40.2
Wilbraham	22.5	New Marlboro	41.2
Dighton	22.6	Petersham	42.2
N. Andover	22.7	Sandwich	42.9
Pepperell	23.4	Swampscott	43.3
Northfield	24.0	Lenox	43.4
Berlin	24.0	Chilmark	44.4
Brookfield	24.2	Leyden	44.5
Williamsburg	24.3	Sandisfield	44.9
Millis	24.4	Hancock	49.1
Holbrook	24.5	Tyringham	49.5
Harwich	24.6	Pembroke	52.2
Greenwich	24.7	Windsor	55.7
Whately	24.8	Wellesley	57.4
Weston	25.1	Holland	66.3
N. Brookfield	25.3	Randolph	68.0
Marshfield	26.0	Shutesbury	70.7
		Holliston	88.1

The Extent of Non-Resident Land Ownership in Agricultural Communities in Massachusetts

The percentage of town acreage owned by non-residents in each of the 71 towns included in this study is shown in Table 1. Of the total of 944,449 acres assessed in 1928 in these towns, 35.7 per cent (337,635 acres) is owned by non-residents. The term "non-resident ownership" is applied here in a broad sense, including both out-of-State residents and those residing in various other sections of the State. It includes also owners residing in neighboring towns with a part of their land situated across the border line. As disclosed by the study of individual towns, however, this factor would account for less than one-tenth of the area owned by non-residents.

TABLE 2. — PROPORTION OF LAND OWNED BY NON-RESIDENTS IN 71 MASSACHUSETTS TOWNS

	Acres	Per cent
Total assessed area	944,449	
Area owned by non-residents	337,635	
Per cent of assessed area		35.7
Land owned by non-residents, equipped with buildings	189,622	
Per cent of total non-resident area		56.2

After allowing for this land owned by the residents of neighboring communities, it will still be found that about one-third of the land in the agricultural communities of Massachusetts is owned by non-residents. The significance of it appears in the fact that in 1920 only 12 per cent of all the farms in Massachusetts were operated by tenants and managers. This condition would indicate, therefore, that the major part of the land owned by non-residents is now used for purposes other than farming, — a conclusion which is further substantiated by the fact that about one-half of the land owned by non-residents is not equipped with any buildings at all.

The distribution of percentages of assessed land area owned by non-residents in various towns is shown in Table 3. In more than half of the towns below 10,000 population over 25 per cent of the area is owned by non-residents and in about 10 per cent of the towns non-residents own over one-half of the area. In a few cases, especially in the towns situated on the coast, non-resident ownership is due to a highly developed recreational utilization of the land, but in the majority of cases it is associated with idle land, mostly of a quality too poor for agricultural purposes.

Table 3. — Distribution of 71 Towns by Percentage of Total Town Area in Non-Resident Ownership

Percentage of Town Area	Number of Towns	Per Cent of Total
Below 20	14	19.7
20 — 24.9	18	25.4
25 — 29.9	8	11.3
30 — 34.9	7	9.8
35 — 39.9	6	8.5
40 — 44.9	9	12.7
45 — 49.9	2	2.8
50 or over	7	9.8
Total	71	100.0

The lowest percentage was found in the town of Bridgewater and the highest in the town of Holliston, the figures being 12.5 per cent and 88.1 per cent respectively. The reason for the small percentage of non-resident land ownership in Bridgewater lies largely in the fact that there is little forest land or land devoted to recreational uses. About one-half of the land area in this town is in farms and the rest is devoted largely to residential purposes. In the town of Holliston the high proportion of non-resident ownership is almost entirely due to the development of summer residences and summer hotels, the area of the town being thus largely devoted to recreational uses.

Relationship Between Non-Resident Land Ownership, Farming, and Various Economic and Physical Factors

The development of non-resident land ownership in Massachusetts agricultural communities is closely connected with the dropping of land out of agricultural use. The character of this relationship is brought out by consideration and analysis of the economic and physical factors of various towns. The factors to be considered here include land values, amount of improved land in farming, proportion of woodland, average elevation of various towns, and other items.

Proportion of Land in Farms

In Chart 3 the percentage of assessed town acreage owned by non-residents is plotted on the curve in ascending succession, beginning with the lowest figure, and is compared with the curve representing the percentages of acreage in farms for the same towns grouped in 10-town averages. From observation of this curve it will be noticed that there is a tendency, although not entirely regular, for the percentage of land owned by non-residents to be higher where the proportion of land in farms is lower. The numerical expression of this tendency will be found in the fact that the half of the towns with the lowest percentage of assessed land owned by non-residents has 53.1 per cent of the area in farms, while the upper half has only 45.6 per cent. The fact that a high degree of non-resident land ownership is associated with a small proportion of land in farms in individual towns provides a basis for judgment as to where this type of ownership is the most prevalent. In the towns where the recreational uses of land are insignificant, non-resident land ownership was found to have been caused almost invariably by the withdrawal of large areas of land from agriculture.

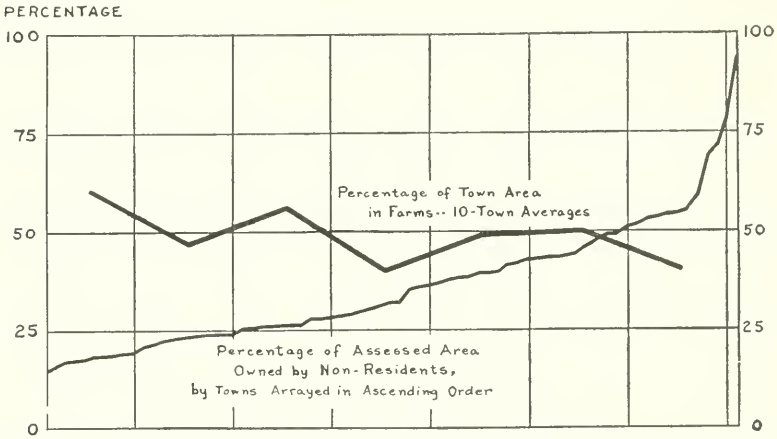

Chart 3. — Percentage of Town Area in Farms as Compared with Percentage Owned by Non-Residents, 71 Massachusetts Towns.

Proportion of Improved Land in Farms

A further analysis connected with the economic and physical conditions of farm land throws some light on the nature and extent of this dependence. In Chart 4 the proportion of non-resident land ownership is considered in connection with improved land in farms, following the procedure explained for Chart 3. A general inspection of the two curves leads again to the conclusion that in general the percentage of non-resident land ownership is greater in the towns where the proportion of improved land in farms is smaller, or in other words where the farms are poorer. This condition is further substantiated by the numerical averages for the percentages of improved land in farms, with the lower half of the towns of the basic curve having 36.2 per cent of the farm land in an improved condition, and the upper half an average of only 31 per cent. In general practice the first step in the process of abandonment of farm land is the decrease in improved acreage on individual

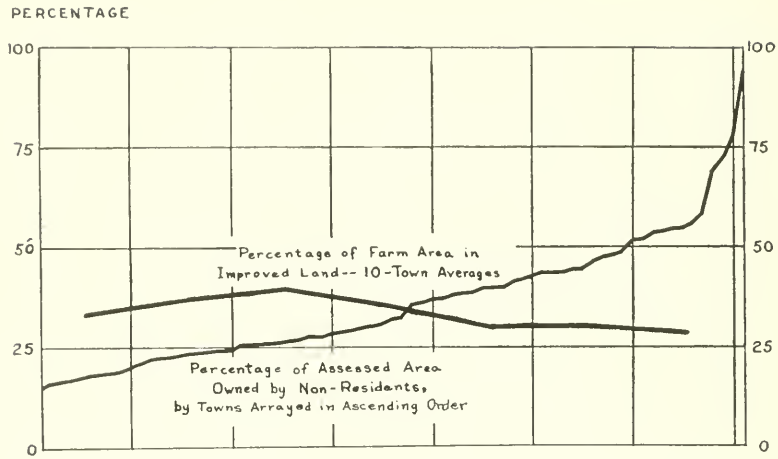

Chart 4. — Percentage of Farm Area in Improved Land as Compared with Percentage of Acreage Owned by Non-Residents, 71 Massachusetts Towns.

farms. Due to unprofitableness of operation, the individual producer is likely to contract his agricultural activities on the poor land and concentrate on the utilization of that section of his farm which contains the best land, with possible changes in the type of farming. A greater portion of the farm is utilized for grazing and then gradually allowed to grow into brush and woods. The presence of a large area of this land in individual farms is a common indication that agriculture, at least in its previous set-up, has become unprofitable in a particular community and that the land is ready either to be abandoned or to be converted to some other use.

TABLE 4. — DISTRIBUTION OF 71 TOWNS BY PERCENTAGE OF IMPROVED LAND ON FARMS

Percentage of Improved Land	Number of Towns	Per Cent of Total
Below 20	8	11.3
20 — 24.9	13	18.3
25 — 29.9	10	14.1
30 — 34.9	8	11.3
35 — 39.9	14	19.7
40 — 44.9	6	8.5
45 — 49.9	5	7.0
50 or over	7	9.8
Total	71	100.0

Farm Land Values

Similar evidence is provided by analyzing non-resident land ownership in connection with farm land values, although the latter are characterized by much greater fluctuations. In many sections of Massachusetts, farm land often derives its value from its potential significance for residential, recreational or other uses.

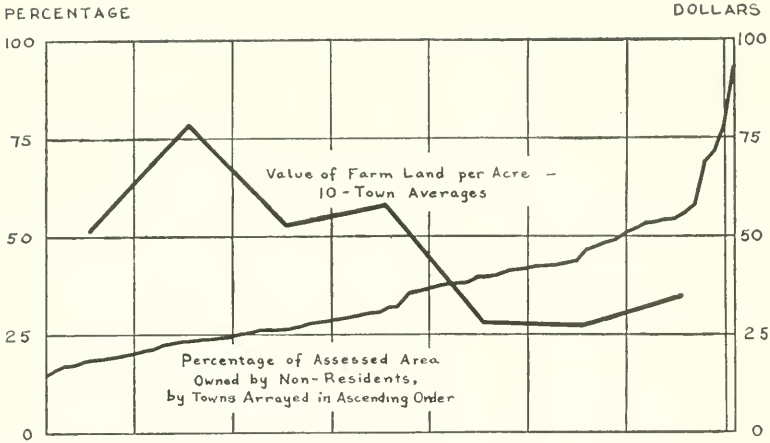

Chart 5. — Value of Farm Land per Acre and Percentage of Acreage Owned by Non-Residents, 71 Massachusetts Towns.

For this reason in some communities farm land which is poor and is but slightly cultivated commands a comparatively high price. It can not be expected, therefore, that a considerable amount of land held by non-residents for non-agricultural purposes will be necessarily connected in all towns with a low value of farm land. The irregularity of this movement is well demonstrated in Chart 5. Where the land owned by non-residents is merely inferior farm land abandoned by agriculture without immediate prospects of being used for any other purpose, there is a distinct association between low farm land values and a high percentage of non-resident land ownership. This condition is especially marked in the interior towns like Hancock, Windsor, Shutesbury, Holland, and Sandisfield, all of which have average farm land values below $20 per acre and over 50 per cent of their area in non-resident ownership. This relationship, however, for the reasons already indicated, does not hold very well in many other towns, and is rather reversed in the shore towns and in the thickly populated eastern sections of the State. The farm land values are here distinctly affected by more profitable land uses, and large sections of land are being intensively utilized especially for recreational purposes. In the towns like Holliston, Randolph, Pembroke, Sandwich, Harwich,

TABLE 5. — DISTRIBUTION OF 71 TOWNS BY AVERAGE VALUE OF LAND PER ACRE IN RESIDENT AND NON-RESIDENT OWNERSHIP

Average Value of Land	Non-Resident Ownership		Resident Ownership	
	Number of Towns	Per cent of Total	Number of Towns	Per cent of Total
Below $50	44	62.0	35	49.3
$50 — 99.99	12	16.9	17	23.9
100 — 299.99	8	11.3	13	18.3
300 or over	7	9.8	6	8.5
Total	71	100.0	71	100.0
Average value per acre	$66.19		$84.48	

and others situated near or on the coast the average farm land values are exceptionally high, reaching as high a level as $160 per acre in Harwich on Cape Cod, in spite of the fact that in most of them one-half or more of the area is in non-resident ownership.

With the exception of the specific sections above noted there is no definite indication, however, that high values of land cause the abandonment of farming in large areas. In about one-half of the 71 towns included in this study, the average value of land owned by residents was above $50 per acre, while only 38 per cent of the towns reached this figure in the case of non-resident ownership. Furthermore, the average value of all land held by non-residents is only $66.15 per acre as compared with $84.48 for the land held by residents, indicating that the land of the latter in whatever use it may be is of a more valuable quality.

Elevation of Land

Other things being equal the abandonment of farm land in Massachusetts ordinarily develops in the sections characterized by a predominance of hills and rough land not well adapted for profitable cultivation by agricultural machinery. It is therefore natural to find the towns with a higher elevation having a large portion of their land area taken out of agricultural use. The amount of non-resident land ownership in these towns indicates the extent to which this process goes.

An attempt has been made in this study to estimate the average elevation of Massachusetts towns on the basis of the figures given by the United States Geological Survey. The data thus obtained are compared in Chart 6 with percentage of non-resident land ownership in the same towns. The comparison of the two curves on the whole upholds the previous statement about the abandoned farm land. There is a definite tendency toward a higher percentage of non-resident land ownership in the towns having a higher average elevation. In fact, the half of the towns with the lowest percentage of non-resident land ownership has an average elevation of only 487.1 feet as compared with an average elevation of 726.9 for the upper group of towns.

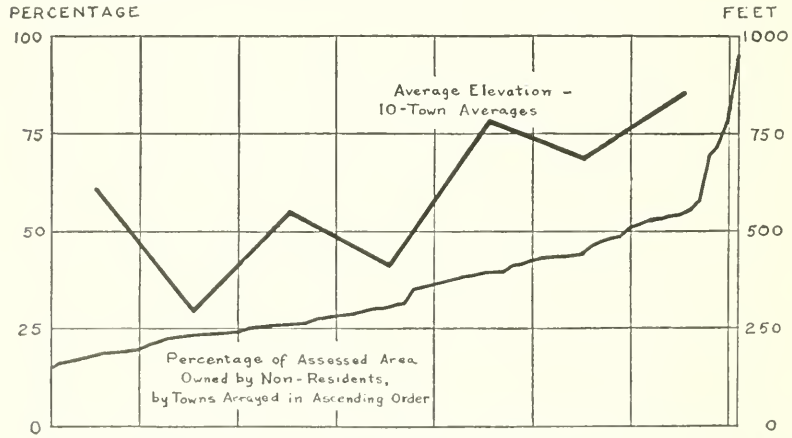

Chart 6. — Average Elevation and Percentage of Acreage Owned by Non-Residents, 71 Massachusetts Towns.

From the analysis of the factors so far presented it appears that non-resident land ownership tends to develop in the towns with inferior agricultural conditions, as indicated by the amount of land in farms, percentage of improved land, and values of farm land. It tends to develop also in the towns with a small amount of level land.

While the hilly sections of Massachusetts are not very favorable for agricultural land utilization they are well suited for the development of forests. Many of them in addition have attractive scenery which will make them more and more desirable for summer residences and other recreational purposes. It does not seem therefore that the development of recreational and forestry uses will conflict here to any great extent with the farming industry, and in most instances this development will offer the best solution of the land utilization problem. Only in the towns situated close to the large centers and on the coast have the residential and recreational uses actually encroached upon farming land.

Utilization of Land in Non-Resident Ownership

In order to determine the kind of land utilization on the areas held in non-resident ownership, detailed information was obtained on each individual property in 5 towns situated in different sections of the State: New Ashford in Berkshire County, Paxton and Princeton in Worcester County, Warwick in Franklin County and Topsfield in Essex County. The condition of these towns as shown in Table 6 varies widely both in percentage of assessed area in non-resident ownership and in the proportion of town land in farming. In the towns of New Ashford and Warwick, with three-fourths of their assessed land in non-resident ownership, a high percentage of this land is in woodland and brush. This condition is characteristic of most of the inland towns which have suffered a great loss in their farming area. Part of this abandoned farm land is already being utilized for the development of forests, summer homes, and other recreational purposes, but there are still available large areas for new types of utilization, even assuming that no more land will be taken out of farming. In a town like Warwick, where a very small portion of the land is at present in farming and almost four-fifths of the area owned by non-residents is in brush and woodland, there is considerable room for this development. Although some of this land is now being taken up for State

TABLE 6. — FARMS, FARM ACREAGE, AND UTILIZATION OF LAND OWNED BY NON-RESIDENTS IN FIVE TOWNS

	New Ashford	Paxton	Topsfield	Princeton	Warwick
Number of farms, 1930	16	52	41	71	89
Land in farming, 1930:					
Acres	2,891	5,535	4,356	12,036	6,017
Per cent of total area	33.0	58.0	53.2	53.1	25.3
Percentage of assessed acreage owned by non-residents, 1928	75.5	48.1	25.7	37.1	76.7
UTILIZATION OF LAND OWNED BY NON-RESIDENTS, BY PERCENTAGES					
Woodland and brush	64.9	14.7	9.9	26.3	79.0
Summer homes	25.7	17.5	16.8	28.2	7.0
Country estates not used for farming	....	11.5	45.8	20.4	....
Commercial	5.2	2.6	11.9	2.4	....
Rented or used for farming	3.3	15.0	10.0	12.8	10.5
Watersheds	....	27.7	....	....	....
Borderline farms	.9	11.0	5.6	9.9	3.5

forests, there are in addition good opportunities for part-time farming and summer homes.

The towns of Topsfield and Princeton, with about one-third of their assessed area owned by non-residents, represent a more balanced picture of land utilization. In the first place, the proportion of non-resident land ownership is smaller than in the first two towns, and in the second place, this area is being utilized more fully. The waste or idle land covered largely by brush and inferior woods occupies a comparatively small portion of the total non-resident owned area in these towns, being only about 10 per cent in Topsfield. One of the reasons is that the latter town is situated in a more thickly populated section of the State, and its land utilization is affected by both residential and recreational factors. In addition almost half of its non-resident owned land is taken up by country estates, while a considerable portion is devoted to summer homes, and to commercial and industrial uses. Under these conditions, in towns of this type there is no acute problem of utilizing the idle acres. There has undoubtedly been an encroachment of other uses of land on agriculture in this town as in many eastern towns of the State situated near the coast. This is well substantiated by the fact that the average value of farm land has increased in this town in the five-year period prior to 1930 from $128 to $218 per acre.

In the town of Princeton the utilization of the non-resident owned area is in a less developed condition. Although almost one-half of it is already taken up by summer homes and country estates, the proportion of idle land is still rather high. In the town of Paxton a partial solution of its idle area has been effected through utilization of a considerable portion of the town land for water-sheds, largely for the city of Worcester. In addition, much land has been taken up for summer homes and country estates.

Proportion of Non-Resident Owned Land in Agriculture

The major portion of the non-resident owned land is either idle or is devoted to uses other than agriculture. Very little of it is used for farming. The town of Paxton with 15 per cent of this land in agriculture represents the highest figure for the five towns, while at the other extreme is the town of New Ashford with only 3.3 per cent in agriculture. In addition, allowance should be made for land belonging to residents of adjoining towns. In practically all cases this land is a part of border-line farms whose dwellings are across the town line. In only one of the five towns the proportion of this land runs to 11 per cent of the total in non-resident ownership, and the five-town average is only about 6 per cent. The country estates owned by non-residents and occupying in some towns a considerable area were found to be little utilized for agricultural purposes. There may be a few saddle horses kept in addition to a cow or two and a small flock of poultry; perhaps a few vegetables are grown, largely for the needs of the hired man. On the basis of these figures it is evident that consideration of non-resident owned land involves uses other than agricultural.

Shifting to Recreational Uses of Land as Demonstrated by the Berkshire Farms

From the analysis of land utilization of non-resident property in the individual towns it appears that much of this land is already dedicated to recreational uses. The latter include not only the land in summer homes and various playgrounds, but also the country estates where little or no farming is practiced. In towns like

Topsfield and Princeton these uses are already responsible for the utilization of about 50 per cent of the non-resident area. However, there are a number of communities in the State with conditions similar to the town of Warwick, where only 7 per cent of this land is taken up for recreational uses, and where there is a possibility of further development for recreation and forestry land without drawing upon the area now in farming.

In a number of these towns with a considerable portion of the land area dropped out of agricultural use, it is becoming an exceedingly difficult problem to maintain the schools, roads and other local institutions out of local taxes. The amount of taxes collected on the land which is idle and without any improvements on it is of necessity limited. Although it has been found in the process of investigation that abandoned land owned by non-residents is generally taxed higher than land of equivalent quality still in farms, the absence of improvements on this land leads to a smaller total valuation.

Where poor quality farm land is being bought with the intention of utilizing it for some other purpose it eventually brings benefit to the agricultural community and the remaining farm population. This condition is well demonstrated by the record of 50 farms in Berkshire County which changed hands between 1925 and 1930. As will be seen from Table 7, over one-half of the land sold with these farms went into recreational and residential uses. (Inasmuch as this represents only a specific group of transactions, the percentage for all farms sold in this county will not necessarily be as high.) The erection of new buildings and other improvements which accompanied the bringing of land into these new uses resulted in increasing the valuation and the amount of collected taxes. Although the addition of new values through improvements has been effected on all former farms after the change of ownership, those sold for recreational and residential purposes have benefited to the greatest extent. This additional basis for taxation enables many towns to obtain a greater income without imposing any new burdens on the farming population.

TABLE 7. — CHANGES IN VALUE AND LAND UTILIZATION OF FIFTY FARMS SOLD IN BERKSHIRE COUNTY IN THE PERIOD FROM 1925 TO 1930.

Purpose Sold For	Farms Sold		Acres		Selling Value	Present Value	Increase in Value Per cent
	Number	Percent	Number	Percent			
Farming	17	34.0	2,550	41.6	$106,100	$124,600	17.4
Recreational and residential uses	30	60.0	3,225	52.5	123,000	231,400	88.1
Country estates	3	6.0	360	5.9	20,900	35,000	67.5
Total	50	100.0	6,135	100.0	$250,000	$391,000	56.4

Out of a total of 50 Berkshire farms investigated, 39 were sold because of retirement, death, or unprofitableness of operation. From this evidence there is no basis for concluding that the sale of farms was due to any considerable extent to competition for land between farming and other uses. Most likely much of the land taken up for recreational and other uses would merely have been added to the abandoned areas already present in different communities.

One adverse influence of the new land developments on the farming population has been brought out by an occasional complaint by some of the farmers that the

country estates offered competition for farm labor by paying higher wages. This condition is more than compensated however, by the fact that the advent of new uses of land gives an opportunity for many local people to obtain profitable employment by working on the improvements and taking care of summer homes and country residences. In addition there is available a profitable local market for the sale of farm produce, especially to the summer residents. This and the contribution to taxes in various towns amounts to considerable benefit to the local farming population.

From the standpoint of the social institutions in small communities, the presence of a large number of people during only a limited season of the year is not always beneficial. The summer residents are not likely to take much interest in local schools and other local institutions. Nevertheless, the financial benefit which accrues to these rural communities from additional taxes and a better market for agricultural commodities results in greater support and improvement of local institutions.

Importance of Recreational Property in Massachusetts

Irrespective of the future growth of recreational land utilization, its position is already of considerable importance in Massachusetts communities from the standpoint of real estate valuation and taxation. According to the recent survey by the Massachusetts Industrial Commission, the total value of recreational property in the State amounts to $189,359,000. In the 71 towns included in the present study, with a total value of real estate of $244,016,030, recreational property amounts to $34,444,272 representing about 14.5 per cent of the valuation and paying the same proportion of total taxes on land and buildings.

Table 8. — Valuation of Recreational Property in Massachusetts.

	All Towns and Cities		71 Towns in this Study	
Recreational Property	Valuation	Per cent of Total	Valuation	Per cent of Total
Non-commercial:				
Owned by Massachusetts residents	$115,218,711	60.8	$23,498,977	68.2
Owned by non-residents	38,209,726	20.2	5,976,029	17.4
Commercial	35,930,743	19.0	4,969,266	14.4
Total	$189,359,180	100.0	$34,444,272	100.0

As will be seen from this table, a little over 20 per cent of the non-commercial recreational property in Massachusetts is owned by people residing outside of the State, and 19 per cent is represented by commercial recreational property, such as summer hotels, golf courses, boys' and girls' camps, roadside camps and cottages, etc. From the standpoint of values, the recreational property is especially significant in the sections near the shore. As compared with this the inland towns with their scenery, lakes and country surroundings do not reach the same degree of development.

Among the individual inland sections Berkshire County occupies the most important place in its recreational development of land resources, but it is far behind Essex County, the most important on the basis of valuation. The high valuation in this county is not surprising when we consider that some of the individual towns on the coast are almost entirely devoted to recreational purposes.

TABLE 9. — VALUATION OF RECREATIONAL REAL ESTATE IN MASSACHUSETTS, BY COUNTIES

County	Valuation of Non-Commercial Recreational Property		Valuation of Commercial Recreational Property	Total Recreational Property
	Owned by Massachusetts Residents	Owned by Out-of-State Residents		
Essex	$28,298,455	$10,285,230	$9,445,140	$48,028,825
Plymouth	39,149,243	2,727,265	2,369,998	44,246,506
Barnstable	25,183,127	12,625,605	4,206,823	42,015,555
Norfolk	6,961,750	603,725	2,676,099	10,241,574
Dukes	3,517,733	3,116,583	1,306,907	7,941,223
Berkshire	1,094,485	4,439,336	1,958,112	7,491,933
Middlesex	1,750,560	215,040	4,488,490	6,454,090
Worcester	2,379,859	433,578	2,501,141	5,314,578
Bristol	2,672,395	1,446,925	587,945	4,707,265
Nantucket	2,446,820	1,631 200	613,460	4,691,480
Suffolk	.....	.....	3,900,350	3,900,350
Hampden	697,205	145,925	1,370,698	2,213,828
Hampshire	824,081	182,729	403,460	1,410,270
Franklin	242,998	356,585	102,120	701,703
Total	$115,218,711	$38,209,726	$35,930,743	$189,359,180

In the town of Gosnold (Dukes County) the valuation of recreational real estate rises as high as 95.3 per cent (Table 10) of the total valuation, while in towns like Eastham and Dennis on Cape Cod over 80 per cent of their real estate values is in recreational uses.

TABLE 10. — TWENTY MASSACHUSETTS TOWNS WITH HIGHEST PROPORTION OF TOTAL VALUATION IN RECREATIONAL PROPERTY

Towns	Valuation of Recreational Land	Total Assessed Valuation	Per Cent Recreational of Total
Gosnold	$1,169,980	$1,227,811	95.3
Oak Bluffs	3,116,505	3,693,935	84.4
Eastham	877,705	1,047,541	83.8
Dennis	2,200,000	2,746,720	80.1
Scituate	8,300,610	11,864,675	70.0
Manchester	7,502,135	10,952,135	68.5
Wellfleet	1,123,650	1,706,417	65.8
Hull	10,944,705	16,930,395	64.6
Sandisfield	350,000	574,675	60.9
Salisbury	1,625,860	2,709,280	60.0
Falmouth	11,039,982	19,124,247	57.7
Barnstable	11,629,580	20,219,610	57.5
Monterey	357,944	628,042	57.0
Chatham	2,836,140	5,115,190	55.4
Harwich	2,830,900	5,140,680	55.1
Yarmouth	2,137,000	3,974,725	53.8
Marshfield	3,736,865	7,037,850	53.1
Stockbridge	2,568,850	4,913,275	52.3
Mattapoisett	1,698,345	2,318,685	51.2
Bourne	4,167,794	8,192,240	50.9

Where recreational property becomes a major factor in any community it necessarily affects the value of local farm land. This condition makes itself felt even in the inland towns and is well demonstrated by several Berkshire towns where farm land values are far above the average for both the County and the State. In the section adjoining the coast there are a number of towns where the average value of farm land exceeds $500 per acre.

In contrast with the intensive development of recreational property in the coastal regions and some sections of Berkshire County, a good many inland communities with attractive physical surroundings are still unutilized or not sufficiently utilized in the way of recreational land development. The presence of large areas of abandoned farm land in these towns and comparatively low land prices offer a possibility of beneficial use of these resources for recreational purposes.

Forest Land Utilization in Massachusetts

Whatever may be the future course in the utilization of land which is already abandoned or may be released from farming, the major part of the total land area in Massachusetts is now covered by forest, including under that term all the land covered by some growth of trees or inferior brush. According to estimates of the Department of Conservation, there is in the State a forest area of about 3,000,000 acres or about 60 per cent of the total area. Of this total only 826,569 acres, or less than one-third, is in farms. About one-half of the wooded area in farms is wholly or partly utilized for pasture, the other half being largely brush and waste land. Better utilization of the wooded area in farms will go a long way toward improving the financial condition of many farmers. Greater attention by the farmer to the possibility of developing his woodlot will make it an asset to the farm enterprise instead of a burden as it frequently is.[2] It will increase the production of material consumed on the farm in the form of fuel, fencing and lumber, and furnish employment to farm labor in slack seasons. In addition, it will bring cash revenue, obtained from periodical cuttings systematically arranged. There is also the possibility of creating local markets for farm products, and of bringing other advantages to the farming population through the development of local woodworking industries because of the presence of a greater supply of needed raw material.

The activities of the Forestry Department through its extension service contribute towards the improvement of woodlots on farms and on other tracts of land owned by individuals. The Department is authorized by law to examine woodlands or waste lands and to advise owners on their care or management, covering such problems as improvements in cuttings, forest planting, marketing forest products and control of pests.

The major portion of the woodland, over 2,000,000 acres, is, however, outside of the farms and is the main reservoir to be drawn upon to supply land for scientific forestry and for rapidly expanding recreational and other uses. Practically the entire area owned by non-residents is represented by some kind of forest land. Any future land policy dealing with the problem of utilizing this area will inevitably take into consideration the possibility of developing a considerable portion of this land into well-managed forests under public or semi-public ownership. At the present time there is already an orderly utilization of small areas for the cultivation of trees in state forests, town forests, various public reservations, and public parks.

There were, at the close of 1930, 47 state-owned forests with a total area of about 115,000 acres. These forests vary in size from 8 acres to 13,652.6 acres, represented by the October Mountain Forest. In addition there were twenty public reservations situated in various sections of the State.

There were also 90 town forests with a total area of 25,500 acres. The State Forestry Service furnishes trees free of charge to plant these forests, with the result that about one million trees have been planted in them annually during the last few years.

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[2] U. S. Department of Agriculture Bulletin No. 1117, "Forestry and the Farm Income." 1923.

TABLE 11. — ACREAGE OF MASSACHUSETTS STATE FORESTS

Forest	Area (acres)	Forest	Area (acres)
1 Myles Standish	8,869	25 Shutesbury	638
2 Shawme	8,336	26 Warwick	1,240
3 Martha's Vineyard	4,473	27 Wendell	4,966
4 Foxborough	662	28 Worthington	225
5 Harold Parker	1,400	29 D. A. R.	1,020
6 Ashburnham	1,208	20 Blandford	1,735
7 Barre	582	31 Brimfield	1,381
8 Hubbardston	811	32 Tolland-Granville	4,682
9 Leominster	1,890	33 Arthur Warton Swann	987
10 Oakham	802	34 Bash Bish	390
11 Otter River	1,817	35 Beartown	7,614
12 Oxford	29	36 Clarksburg	1,864
13 Petersham	248	37 Mohawk Trail	5,420
14 Spencer	651	38 October Mountain	13,653
15 Sutton	363	39 Otis	3,202
16 Templeton	609	40 Peru	1,588
17 Westminster	342	41 Pittsfield	1,156
18 Colrain	1,206	42 Sandisfield	3,895
19 Conway	1,563	43 Savoy Mountain	7,858
20 Erving	4,437	44 Windsor	1,450
21 Hawley	2,411	45 Willard Brook	310
22 Mount Grace	1,066	46 Fed. of Women's Clubs	8
23 Monroe	4,117	47 Huntington	441
24 Northfield	235	Unassigned	1,093
		Total	114,943

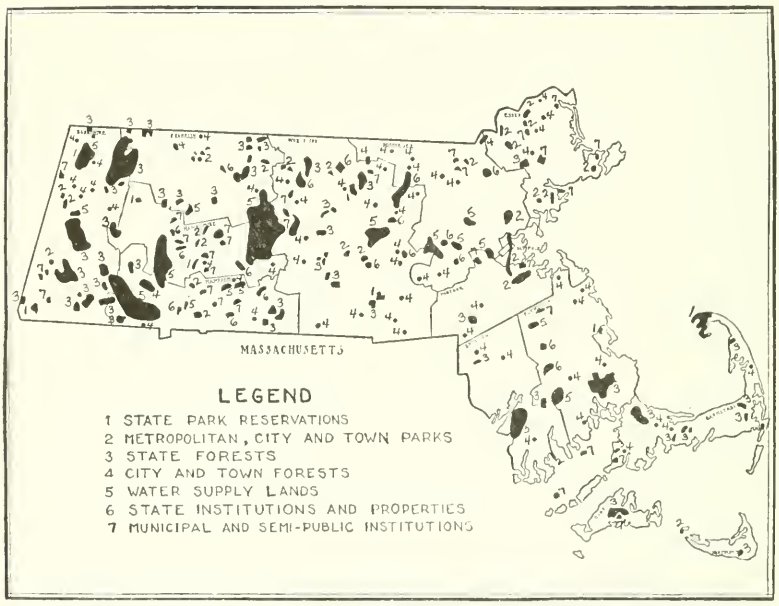
Several forest areas are held by a semi-public organization, the so-called Trustees of Public Reservations, who control a total of about 790 acres.

All the state forests, town forests and forests owned by other public and semi-public organizations include at present about 200,000 acres. This still leaves about 2,000,000 acres of wooded land in private ownership outside of farms. Some of this land is now used for recreational purposes. Although a portion of the total area will be gradually transferred into public ownership, the major part will probably remain for a considerable time in private hands. It is, therefore, important to afford better opportunities for reforestation and development of these areas by private individuals. To meet this situation the legislature passed in 1922 the forest classification act under which "forest land, coming within the terms of eligibility, can be separately classified and thereafter pays a tax on land value only, with a products tax payable at the time the timber is cut." When the timber on such land is cut off, a yield tax of 6 per cent is assessed on the stumpage value of the material cut. Under the provisions of this law 93 owners in 47 towns had placed in the classification of forest land 24,553 acres up to the end of 1929.

The management of present idle tracts of land to secure forest crops has great possibilities in influencing agricultural land utilization. Through maintaining or recreating local industries dependent on wood for their raw materials, it will have a stabilizing effect on the local population and maintain better markets for local products. To the extent that forest development will occupy areas submarginal for regular farming, it will lessen the hazard of unwise use of poor land and prevent considerable losses to producers established on areas unsuitable for agricultural cultivation.

Possibilities of Extending Land Areas in Public Ownership

After making a special survey, a committee appointed by the Governor of the Commonwealth recently presented a tentative plan for the development and enlargement of the present areas held by the State and other public and semi-public bodies. The basic recommendations of the plan include a proposal for a considerable extension of the land areas held in public ownership in various sections of the State.



Public and Semi-Public Areas in Massachusetts.

In any attempt to include new areas in public ownership, careful consideration should be given to the general effect on the rural communities concerned, which may be affected adversely if indiscriminate extension of public ownership is made. The indications are that public ownership will of necessity take care of only a minor portion of the land which is available for recreational and forestry uses. The main problem lies with the utilization of these areas under private ownership, which will include both forestry and other uses. In many communities, with improvement of roads and increase of population, there is likely to be a considerable development of part-time farming. For this reason caution should be exercised in acquiring present areas for public forests. Likewise, it is important to see that the development of forestry in any particular town does not encroach upon the farming or local population. This condition will arise if the town receipts from public land are not equivalent to what may accrue to the town from other uses of the land within the near future. In extending public ownership in any particular locality, therefore, the immediate prospects for land utilization as well as the

present condition should be taken into consideration. The most important guides in regard to the present condition are the proportion of land in farming, the percentage of improved land in farms, the value of farm land, and the density of population. If the major part of the town is represented by abandoned farm land, it might be to the advantage of the community and all concerned in locating public forests to take up the whole town area in order to lift from the local people the burden of paying taxes for schools, roads, and other public expenditures.

Summary and Conclusions

1. A considerable decline of the land area in farming and of the proportion of improved farm land in the last few decades has resulted in the presence in Massachusetts of many idle acres which create an important problem in land utilization.

2. Largely as a result of the abandonment of farm land, about one-third of the total area in towns with a population of less than 10,000 is owned by non-residents.

3. The greatest abandonment of farm land and development of non-resident ownership occurred in the hilly sections and communities with poor farm land as indicated by the percentage of the town area in farming, the amount of improved land in farms, and farm land values.

4. In the towns situated on the coast and in some inland towns, especially in Berkshire County, the land owned by non-residents is utilized to a great extent for recreational purposes. However, most of the abandoned farm land held by non-residents in other areas is represented by idle acres covered by brush and inferior woods.

5. Except for the coastal towns and a few towns in Berkshire County, there is no substantial evidence that development of recreational uses encroaches upon farm land.

6. The development of recreational uses in communities with a large area of idle land benefits the local population by providing a greater amount in tax receipts, a local market for agricultural products, and some employment for the local people. The negative effect in some cases is found in lack of interest in local institutions and occasional competition with the farmers for hired labor.

7. In many towns there are exceptional opportunities for the development of recreational uses of land, and while the number of summer homes in these areas is increasing it is not commensurate with the amount of land available.

8. Although the indications are that with a further development of good roads a considerable amount of the present area of idle land will be taken up in the near future for part-time farming, recreational and residential uses, the major part of it has to be utilized for the growth of trees. At the present time about 115,000 acres of land are in 47 state forests, 25,500 acres in town forests, and small areas in forest land held by various public and semi-public organizations.

9. Any program for land utilization in individual towns or sections of the State should be based on a careful study of local conditions. This would involve an intensive survey of both physical and economic factors. As a general outgrowth of this study, the following policies are recommended:

a. In planning further acquisition of land by the State and other public institutions for forestry or recreational purposes, it is advisable to exercise more care not to include towns where the improvement of present roads and the construction of new highways is likely to create in the near future a considerable development of part-time farming and summer homes.

b. Where the major part of the town is represented by abandoned farm land, it may be advisable from the standpoint of economies in local taxation and expenditures to convert the whole town instead of part of it into state forest by effecting an arrangement for the exchange of land at present occupied for farming for land in adjoining communities.

c. In the last few years the state forestry extension service has been instrumental in bringing about a considerable improvement in the condition of woodlots on many farms. The continuation and expansion of this service are essential to a better utilization of unimproved farm land which now occupies almost 25 per cent of the total land area of the State.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE.
3M-2-'33. No. 7627

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

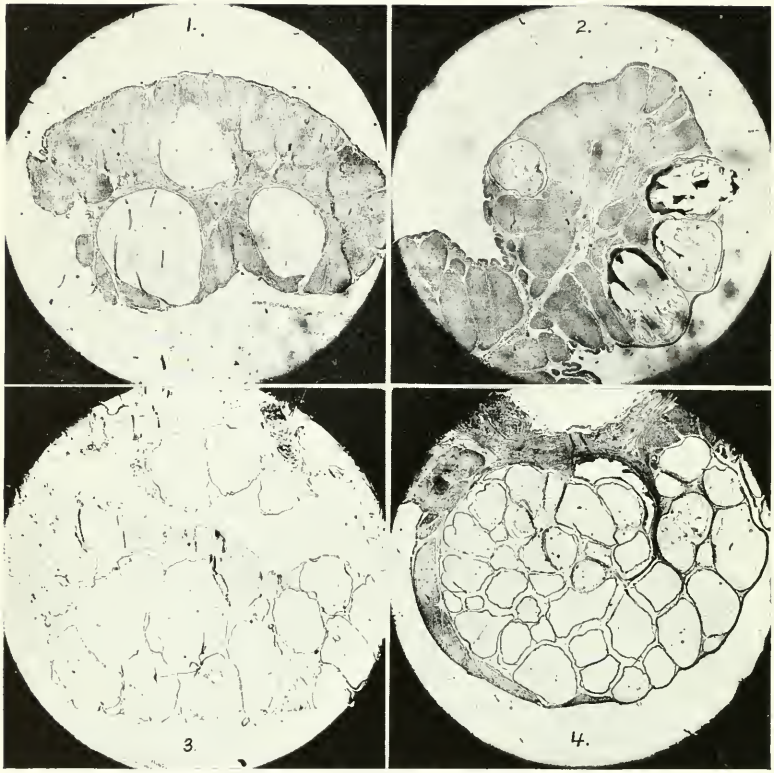
BULLETIN No. 295 MAY, 1933

The Immunology of Infectious Laryngotracheitis

By Charles S. Gibbs

Contagious diseases are sometimes controlled by taking advantage either of serological tests or of vaccination procedures based on immunology. The immunology of infectious laryngotracheitis has never been worked out. While this study is not exhaustive, progress has been made toward a better understanding of the disease, and a tentative vaccination method for its control is advanced from the laboratory stage to more extensive experiments in the field.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.



Traumatic Cysts in the Mucous Membrane of the Bursa of Fabricius

1. Cockerel MF-89852
2. Pullet MF-89862
3. Cockerel MF-89879
4. Cockerel MF-89923

(Photomicrographs by Professor W. H. Davis, Botany Department, Massachusetts State College)

THE IMMUNOLOGY OF INFECTIOUS LARYNGOTRACHEITIS

By Charles S. Gibbs,
Research Professor of Veterinary Science

In undertaking this study it was necessary first of all to determine whether birds could be artificially immunized to infectious laryngotracheitis or not. After having determined this point, and realizing that very little immunological work has been done with birds, it was felt that some preliminary experiments under controlled conditions in the laboratory would yield results more quickly than could be expected in the field. This report shows that this anticipation has been fulfilled and a foundation has been laid for attempting field work in an experimental way as the next step forward in the investigation of this project.

In the experiments reported, attempts were made to immunize birds by inoculating the virus into some portion of the body other than the respiratory tract. Naturally, the exudate and tissues containing the virus had to be modified to facilitate inoculation, and this may have had some effect upon the results, but the general principle of keeping the virus away from the respiratory tract was adhered to as much as possible.

FEEDING EXPERIMENTS WITH UNFILTERED VIRUS

On nine consecutive days, 36 chickens six weeks old were fed infectious laryngotracheal exudate in gelatin capsules without any of them showing symptoms of disease. Nine control chickens from the same flock, inoculated intratracheally with the same virus, contracted the disease and seven of them died. Four weeks after the feeding had been completed, the 36 chickens were inoculated intratracheally with fresh infectious laryngotracheal exudate, and all of them came down with the disease, from which 29 died. This experiment indicates that no lasting immunity was stimulated by feeding chickens six weeks old with virulent infectious laryngotracheitis virus for nine days.

SEITZ FILTERED VIRUS

Intravenous Inoculation

1. *Single Inoculations of Diluted Virus*

An attempt was made to immunize birds by inoculation in the wing veins with various dilutions of infectious laryngotracheitis virus which had been passed through Seitz E. K. Schichten filters to remove bacteria. The first part of this project, or the filtrations through the Seitz filters, was the most difficult to control, because no satisfactory way of standardizing the virus had been discovered, and the filtrates could not always be depended upon to contain sufficient virus to produce the desired degree of immunity unless carefully checked by adequate controls. When it was found by means of the controls that the virus did not pass the Seitz filters in sufficient quantity to infect susceptible chickens, inoculated intratracheally, the filtrations and inoculations were repeated with fresh virus until satisfactory results were secured.

Sixty-eight chicks, which had never been exposed to infectious laryngotracheitis, were divided into four groups, each group consisting of fifteen chickens for intravenous inoculation and two for intratracheal inoculation or controls. Each

chicken to be immunized was inoculated in the wing vein with 1 cc. of fresh infectious laryngotracheal exudate which had been diluted with physiological saline and filtered through Seitz filters. In Group 1 the filtrate was diluted 1-10, and in Groups 2, 3, and 4 the dilutions were 1-25, 1-50, and 1-100, respectively. The eight controls were inoculated intratracheally with the filtrate as diluted for each group. The results of the intravenous inoculations are reported in Table 1.

TABLE 1. — THE TITRATION OF INFECTIOUS LARYNGOTRACHEITIS VIRUS FOR INTRAVENOUS INOCULATION

		Inoculated intravenously			Controls (inoculated intratracheally)		
			Affected			Affected	
Group	Dilution of virus	Unaffected	Recovered	Died	Unaffected	Recovered	Died
1	1-10	1	4	10	0	0	2
2	1-25	3	7	5	0	0	2
3	1-50	11	2	2	1	1	0
4	1-100	15	0	0	2	0	0
Totals		30	13	17	3	1	4

A study of Table 1 will show that dilutions 1-10, 1-25, and 1-50 were too strong, since 14 chickens contracted the disease in Group 1, 12 in Group 2, and 4 in Group 3. The 1-100 dilution was too weak, for both controls were unaffected.

All of the chickens surviving the intravenous inoculations were inoculated intratracheally with fresh infectious laryngotracheitis virus. The results are given in Table 2.

TABLE 2.—THE RESULTS OF THE INTRATRACHEAL INOCULATIONS OF THE CHICKENS PREVIOUSLY INOCULATED INTRAVENOUSLY (TABLE 1).

Group	Inoculated intratracheally after intravenous inoculation			Controls (both inoculations intratracheal)		
		Affected			Affected	
	Unaffected	Recovered	Died	Unaffected	Recovered	Died
1	5	0	0	–	–	--
2	10	0	0	–	–	–
3	10	3	0	1	1	0
4	8	6	1	0	0	2
Totals	33	9	1	1	1	2

The data in Table 2 show that the four chickens in Group 1 and the seven chickens in Group 2, affected by the intravenous inoculations, were immune to infectious laryngotracheitis. The unaffected chickens in Groups 1 and 2 were immune also. Three of the 11 unaffected chickens in Group 3 contracted infectious laryngotracheitis without fatal termination, while the two affected chickens were found to be immune. Seven of the fifteen chickens unaffected by the intravenous inoculations in Group 4 were affected by the intratracheal swabbings and one died.

One of the control chickens in Group 3, Table 1, was affected by the intratracheal inoculation and the other was not. In Table 2 these chickens are reversed as a result of the intratracheal swabbings. Both of the chickens in Group 4 contracted infectious laryngotracheitis and died, indicating that the virus had been diluted too much, as was suspected.

2. *Intermittent Inoculation of Small Doses of Virus.*

Chickens, six weeks of age, were divided into four groups of 12 each, and inoculated intravenously with tracheal exudate which had been prepared by triturating 1 gram of desiccated tracheal exudate with 25 cc. of saline solution and filtering through a Seitz filter. The chickens in Group 1 were inoculated with 1/4 cc. of the filtered tracheal exudate; those in Group 2, with 1/4 cc. and 1/2 cc. at an interval of seven days; those in Group 3, with 1/4 cc., 1/2 cc., and 3/4 cc. of the same preparation in the same manner; and those in Group 4, with 1/4 cc., 1/2 cc., 1 cc., and 2 cc. Twenty-two controls were swabbed intratracheally and contracted infectious laryngotracheitis and died, while the chickens inoculated intravenously remained unaffected.

Seven days after the final intravenous inoculation the 48 unaffected chickens and two new controls were treated intratracheally with fresh laryngotracheitis virus. The results are shown in Table 3.

TABLE 3. — TESTS OF IMMUNITY IMPARTED TO CHICKENS BY INTERMITTENT INTRAVENOUS INOCULATIONS WITH SMALL DOSES OF VIRUS

Group	Inoculated intratracheally after intravenous inoculation			Controls (intratracheal inoculation only)
		Affected		
	Unaffected	Recovered	Died	Died
1	2	0	10	–
2	4	3	5	–
3	10	2	0	2
4	12	0	0	–
Totals	28	5	15	2

Table 3 indicates that the chickens in Groups 1 and 2 receiving one and two intravenous inoculations of Seitz filtered tracheal exudates, respectively, were not protected against intratracheal swabbings of virulent virus, while the chickens in Groups 3 and 4 receiving increasingly larger doses of the filtrate over longer periods of time were made immune to infectious laryngotracheitis.

The Duration of Immunity

Another flock of chickens as nearly like the preceding as it was possible to secure were treated in a similar manner, except that they were not inoculated intratracheally until a period of four months had passed, in order to allow the immunity time to wear off if it were inclined to do so. The treatments were as follows: Group 1 received 1/4 cc. of the Seitz filtered tracheal exudate diluted 1-25; Group 2, 1/4 and 1/2 cc.; Group 3, 1/4, 1/2, 3/4, and 2 cc.; and Group 4, 1/4, 1/2, 3/4, 2, 2, 3/4, 1/2, and 1/4 cc. The doses were administered at weekly intervals, and the fluid was warmed to body temperature each time. The results are shown in Table 4.

This experiment indicates that chickens may be immunized to infectious laryngotracheitis by inoculation with small doses of properly diluted infectious laryngotracheal exudate in physiological saline solution at seven-day intervals until four or five doses have been given, over a period of twenty-eight days.

Success or failure to secure an enduring immunity by this method depends upon the virulence of the Seitz filtered virus. This virulence may be determined by inoculating controls of the same age and resistance as the birds it is desired to immunize. If at any time the filtrate fails to cause active symptoms of infectious laryngotracheitis in the controls, its value as an immunizing agent should be questioned.

TABLE 4. — TESTS OF THE DURATION OF IMMUNITY IMPARTED TO CHICKENS BY INTERMITTENT INTRAVENOUS INOCULATIONS WITH SMALL DOSES OF VIRUS

Group	Number of doses	Inoculated intratracheally four months after intravenous inoculation			Controls (intratracheal inoculation only)	
			Affected		Affected	
		Unaffected	Recovered	Died	Recovered	Died
1	1	1	1	10	0	2
2	2	1	3	8	0	2
3	4	11	1	0	0	2
4	8	12	0	0	1	1
Totals		25	5	18	1	7

Because of the difficulties in administration, uncertainty of results, and expense, the intravenous immunization of chickens against infectious laryngotracheitis may never be practical under field conditions; yet it has served to demonstrate that chickens may be immunized by this method in the laboratory.

Subcutaneous Inoculation

Since it was found that chickens could be immunized by intravenous inoculations of small doses of virus over a period of 28 days, attempts were made to immunize chickens by introducing the virus subcutaneously, in the hope that the skin would retain the fluid and the immunizing agent would be gradually absorbed by the tissues. Most of these experiments were conducted in the laboratory, although one project was carried into the field. These experiments demonstrated very clearly that it is impossible to immunize satisfactorily either chickens or fowls on a large scale by this method, because the skin of the bird is thin, soft and rather porous, so that it does not retain solutions for the absorption of the virus for any great length of time. All of the viruses had to be diluted and filtered, because concentrated unfiltered tracheal exudates tended to produce abscesses and suppurations.

In some of the experiments a physiological saline filtrate of the tracheal exudate containing the virus was mixed with one-half its volume of sterile glycerol before inoculation, in the hope that the mixture would be retained longer and absorbed more gradually by the tissues, as occurs in glycerolized bile (Gibbs, 1925), and antirinderpest serum in cattle (Gibbs, 1929). For some reason not fully understood, the results were unsatisfactory under field conditions, although the experiments with birds confined in cages were encouraging. The glycerol did not destroy the virus, for it had previously been determined that glycerol in one-half its volume of physiological saline solution is one of the best liquid preservatives of infectious laryngotracheitis virus known.

The following protocol on the subcutaneous inoculation of various preparations of tracheal exudates illustrated the efficacy of the glycerol and physiological saline preparation over the others under laboratory conditions.

Chickens, two months old, were divided into six groups of 10 each, while a control group of 12 chickens were placed in cages so as to provide two controls for each preparation of virus. The subcutaneous inoculations were made on the sides of the breast, under the wings, as follows:—

Group 1 was inoculated subcutaneously with 2 cc. of tracheal exudate, diluted 1-25 and filtered through sterile Whatman paper to remove the coarse particles.

Group 2 was treated in the same manner with 2 cc. of the tracheal exudate solution, diluted 1-25 and filtered through a sterile Seitz filter, and Groups 3 and 4 were inoculated with two and three doses of the same liquid at weekly intervals. Groups 5 and 6 were treated with tracheal exudate which had been diluted 1-25 in saline and glycerol mixed in equal volumes.

TABLE 5. — THE RESULTS OF SUBCUTANEOUS INOCULATIONS OF INFECTIOUS LARYNGOTRACHEITIS VIRUS

Group	Inoculated subcutaneously				Controls (inoculated intratracheally)
			Affected		
	Unaffected	Abscesses	Recovered	Died	Died
1	2	2	3	3	2
2	3	0	4	3	2
3	3	0	3	4	2
4	6	0	3	1	2
5	7	0	2	1	2
6	8	0	2	0	2
Totals	29	2	17	12	12

Table 5 shows that the chickens in Groups 1,2,3, and 4 were not as well protected as those in Groups 5 and 6. Also, it shows that the virus which was inoculated intratracheally was virulent, for all of the controls died. Obviously the degree of immunity imparted by subcutaneous inoculations is relative, depending upon the virulence of the virus, the number of inoculations, and the viscosity of the fluid injected.

Since the farmer with whom the field project was carried on felt that three or more inoculations, involving as many handlings of the birds, was a serious drawback, the study of the subcutaneous method was abandoned as being impractical under range conditions.

TISSUE VACCINES

The success of Boynton (1928), Kelser (1928), and Nakizaki et al. (1926) with tissues vaccines for rinderpest, the experiments of Laidlaw and Dunkin (1927, 1928) with distemper in ferrets and dogs, and Pasteur's rabies vaccine suggest that possibly a similar biologic might be developed for infectious laryngotracheitis, since Gibbs (1931) and Beach (1931) report finding the virus associated with the tissues of diseased chickens. However, before attempting any vaccinations it was deemed best to approach this project by studying the constancy, the virulence, and the preservation of the virus in the tissues as compared with that in the trachea of the same bird.

By careful manipulation all three points were determined in one experiment as follows:

Twelve chickens, six weeks old, were placed in cages, so that they could be observed and handled better than if allowed to run in a single large room, or colony house. The chickens were inoculated intratracheally with fresh tracheal exudate, and every other day beginning the second day after the inoculation two of the chickens were killed and the liver, spleen, blood, and tracheal exudate removed under aseptic conditions and placed in sterile mortars. The tissues were pounded and rubbed into smooth masses with sterile pestles. Sufficient saline was added to yield a 20 per cent suspension of tissue pulp, and after brief stirring the contents of the mortars were transferred to sterile bottles containing glass beads. The bottles

were shaken vigorously for fifteen or twenty minutes until the fragments were broken up as much as possible. The contents of the bottles were filtered through several layers of sterile cheesecloth into sterile flasks. All of the coarse particles of fibrous tissue, serous and mucous membranes, and trabeculae were thus removed.

Each suspension of tissue was divided into four parts. Part 1 was reserved for control. To Part 2 was added 40 per cent formalin until a final concentration of 0.1 per cent formaldehyde was attained, and the mixture shaken and placed in the ice box for twenty hours before use. A solution of carbolic acid was added to Part 3 until 0.5 per cent phenol was obtained. Glycerol was shaken into Part 4 until a homogeneous mixture was secured, containing about 25 per cent of the fluid. Two chickens six weeks old were inoculated intratracheally with each preparation until the tissues from the twelve original birds on the experiment had been tested and the results noted.

The virus was found in the blood and tissues of four of the chickens soon after external symptoms were noticed, lingered for about 48 hours, and disappeared so that it could not be determined by intratracheal inoculation outside of the respiratory tract.[1] Measured by the comparative mortality of the chickens in the various groups, the virus in the tracheal exudate was more virulent than that in the tissues. Formalin and phenol apparently destroyed the virus in every preparation in which they were used. The gylcerolized tracheal exudates maintained their virulence the best of all, but this preparation has already been studied, and it is unnecessary to discuss it further. No evidence of the virus was found either in the tissues or in the blood just before death as so often occurs in bacterial diseases. The chickens on this experiment apparently died of asphyxiation, due to plugging of either the larynx or syrinx by pseudomembrane.

The results of this experiment indicate that it is impossible to prepare satisfactory tissue vaccines for infectious laryngotracheitis by the methods used in this investigation.

HYPERIMMUNE SERUM

Intravenous Inoculations

Hyperimmune serum was prepared by inoculating pullets intravenously with tracheal exudates, which had been diluted 1-10 in saline solution and filtered through Seitz E. K. Schichten filters. Two cc. were inoculated into the wing veins at five-day intervals until six injections had been made. Eight days after the last intravenous inoculation the birds were killed, the blood drawn into sterile cylinders, and the clot allowed to form at room temperature. Later the clot was lifted from the sides of the cylinders by means of sterile rods, and sterile weights were placed on the surfaces of the clotted blood to press the serum out. After standing in the ice box for forty-eight hours the clear serum was pipetted from the cylinders into a sterile bottle, 0.5 per cent phenol added, and the bottle shaken until a uniform mixture was obtained. The serum was stored in the ice box until the chickens were ready for the experiment.

For these experiments 42 pullets and cockerels three months old, which had never been exposed to infectious laryngotracheitis, were secured. They were divided into three groups of 14 birds each, and inoculated intratracheally with infectious laryngotracheitis virus. Then 10 of the chickens in each group were inoculated intravenously with hyperimmune serum, while four were left as untreated controls. The birds in Group 1 received 1 cc. of hyperimmune serum on

[1] In these experiments the virus appeared to be associated with the erythrocytes, and its antibody with the leucocytes and serum. Investigation is under way to determine this point more fully.

the day symptoms appeared; those in Group 2 received 1/2 cc. on the same day and 3/4 cc. on the day following; while those in Group 3 were treated with 1 cc. of hyperimmune serum two days after symptoms appeared. The results of this experiment are tabulated as follows:—

TABLE 6. — THE RESULTS OF INTRAVENOUS INOCULATION WITH HYPERIMMUNE SERUM

Group	Treated with virus and hyperimmune serum		Controls (virus but no serum)	
	Affected		Affected	
	Recovered	Died	Recovered	Died
1	8	2	0	4
2	10	0	1	3
3	2	8	0	4
Totals	20	10	1	11

Table 6 indicates that one large dose of the hyperimmune serum on the day symptoms appear is not as effective as smaller doses given twenty-four hours apart. Serum administered intravenously two days after symptoms have already appeared, or in other words when the disease is pretty well advanced, is of little value. All of the birds protected by the hyperimmune serum and recovering from the intratracheal inoculations were found to be immune a month later. The reaction in these partially immune birds may have been similar to the serum and virus immunization process so often taken advantage of in hog cholera, rinderpest, and sometimes in dog distemper.

The task of inoculating birds intravenously was slow, painstaking labor, because each bird had to be treated individually and the needle carefully maneuvered into the wing vein. For this reason it was almost impossible to inoculate successfully birds under three months of age. Since infectious laryngotracheitis is primarily a disease of chickens, this method may not be practical on a large scale.

Subcutaneous Inoculations

In order to determine the efficacy of the subcutaneous inoculation of hyperimmune serum, 42 pullets and cockerels three months old were divided into three groups of 14 birds each, and inoculated intratracheally with infectious laryngotracheitis virus. Then 10 birds in each group were treated subcutaneously with hyperimmune serum, and 12 controls, 4 for each group, were not given any serum. The doses of serum for each group varied as follows:-

Group 1 received 1 cc. of serum on the day the tracheas were inoculated, and a second dose was given twenty-four hours later on the other side of the breast. Group 2 was inoculated in the same manner, except that the inoculations were commenced the second day after symptoms appeared. Group 3 was given 1 cc. of hyperimmune serum only on the day symptoms of infectious laryngotracheitis appeared.

In these experiments the hyperimmune serum apparently filtered slowly into the tissues and did not neutralize the virus of infectious laryngotracheitis to any great extent. The best results were secured in Group 1 in which chickens were inoculated before symptoms of disease appeared. All of the surviving chickens were found to be immune a month after recovering from the disease, except the controls and two unaffected chickens in Group 1. The controls died, but the two unaffected chickens in Group 1 recovered.

The results of these inoculations are reported in Table 7.

TABLE 7.— THE RESULTS OF SUBCUTANEOUS INOCULATION WITH HYPERIMMUNE SERUM

Group	Treated with virus and hyperimmune serum			Controls (virus but no serum)
		Affected		
	Unaffected	Recovered	Died	Died
1	2	4	4	4
2	0	2	8	4
3	0	3	7	4
Totals	2	9	19	12

The Duration of Immunity

A determination of the duration of immunity stimulated by the intravenous inoculation of hyperimmune serum was made by selecting 42 pullets and cockerels and inoculating 30 of them intravenously with hyperimmune serum. The birds were given 1/4 cc. of serum the first day and 3/4 cc. the second. The 12 uninoculated birds were held as controls.

Five days after the serum treatments, 10 inoculated and 4 uninoculated controls were picked out of the flock at random, placed in separate cages, and inoculated intratracheally with fresh virus. Ten and fifteen days after the serum treatments, the second and third groups were treated likewise. The results are noted in Table 8.

TABLE 8.— DURATION OF IMMUNITY IMPARTED TO PULLETS AND COCKERELS BY HYPERIMMUNE SERUM

Group	Treated with virus and hyperimmune serum			Controls (virus but no serum)	
		Affected		Affected	
	Unaffected	Recovered	Died	Recovered	Died
1	9	1	0	1	3
2	6	4	0	0	4
3	1	1	8	0	4
Totals	16	6	8	1	11

This experiment indicates that immunity imparted to pullets and cockerels by hyperimmune infectious laryngotracheitis serum is temporary. It had evidently reached its full strength five days after administration, as indicated by Group 1, but soon after this it apparently began to decline so that at ten days after inoculation 4 of the 10 chickens had contracted the disease, but none died, as shown by Group 2. Fifteen days after inoculation practically all of the immunity imparted by the hyperimmune serum had disappeared, as revealed by Group 3, in which 9 of the 10 chickens contracted the disease and 8 of them died.

VACCINATION IN THE BURSA OF FABRICIUS

Since the introduction of antigens directly into the subcutaneous tissues and blood stream did not yield satisfactory methods for immunizing birds against

infectious laryngotracheitis, it was decided to try the bursa of Fabricius, since this organ is lined with mucous membrane, and is some distance from the respiratory tract. Up to this time it was not known that the bursa of Fabricius was susceptible to inoculation with infectious laryngotracheitis. After this point had been determined, Hudson and Beaudette (1932) published their results on the cloacal inoculation of chickens with infectious laryngotracheitis virus; and after the work reported in this bulletin had been completed, they published their "Experiments on Immunization against Laryngotracheitis in Fowls" (1933). The work is based on the same principle as the experiments reported herein, although the method of attack, field covered, and interpretation of results differ in several important respects. However, Beaudette and Hudson have had some access to field work, and probably speak with authority on the practical value of this method for immunizing birds outside of the laboratory.

The Bursa of Fabricius

The bursa of Fabricius, named after Hieronymus Fabricius, the celebrated Italian anatomist and surgeon (Borden, 1922), is a bulblike organ lying dorsally to the cloaca in the chicken. It is fully developed at the time of hatching, continues to increase in size as the bird grows, and reaches its maximum development between four and five months (Schauder, 1923; Otte, 1928). At this time it averages one inch long, three-fourths of an inch wide, and one-tenth of an inch in thickness in the Rhode Island Red. It occurs in both cockerels and pullets. Involution commences near the time of sexual maturity (Jolly, 1913; Riddle, 1928), and in the course of two or three months it is reduced to a narrow fold.

The wall of the bursa of Fabricius is made up externally of a serosa composed chiefly of white fibrous connective tissue, and an internal mucous membrane lined with epithelial tissue. A layer of circular and longitudinal involuntary muscle tissue is located between the serous and mucous membrances. The mucous membrane and some of the muscle tissues are folded longitudinally so that the organ presents a wrinkled appearance internally. The external appearance is smooth. The aperture into the bursa of Fabricius is small and controlled by a sphincter muscle until involution commences. At the time of retrogression, the sphincter muscle gradually loses its elasticity and the opening enlarges until involution is complete. In the adult bird the opening appears as a horizontal slit leading into the bursal fold.

The physiological function of the bursa of Fabricius has been disputed. Retterer and Lelievre (1913) believed it to be concerned in fertilization. Jolly (1911) ascribed a hematopoietic function to it, and Jolly and Levin (1911) stated that it might be associated with nutrition for it degenerates rapidly during starvation, and is abundantly supplied with lymphatics.

Infection of the Bursa of Fabricius with the Virus of Infectious Laryngotracheitis

In starting these experimental studies on the bursa of Fabricius inoculation, it was necessary first of all to determine whether this organ could be infected with the virus of infectious laryngotracheitis, and if so, how long the virus would remain in it.

Twenty-four chickens three months old were selected for this study. Twelve of them had never been exposed to the disease, and the others had been immunized by the intravenous method. All of them were inoculated in the bursa of Fabricius with infectious laryngotracheitis virus, which had been prepared in the following

manner. Desiccated virus was ground up in a sterile mortar with sufficient sterile saline solution to make a thin paste. A pinch of cotton was twisted on the end of a wooden applicator to make a swab that would easily pass through the opening leading into the bursa of Fabricius. The swab was dipped into the paste, and gently pushed through the bursal orifice of each bird and the mucous membrane carefully swabbed, taking care to get between the folds. Beginning the third day after inoculation, a swab was inserted into the bursa of each bird and some of the exudate removed and re-inoculated into the tracheas of chickens which had never been exposed to infectious laryngotracheitis. The results of this experiment are reported in Table 9.

TABLE 9. — THE NUMBER OF DAYS THE VIRUS WAS RECOVERED FROM THE BURSA OF FABRICIUS

Days	Unimmunized birds	Immune controls
1	12	8
2	12	5
3	12	2
4	12	0
5	11	0
6	8	0
7	5	0
8	3	0
9	2	0
10	0	0

In this table the unimmunized birds refer to the 12 chickens which had never been exposed to infectious laryngotracheitis until they were vaccinated in the bursa of Fabricius, and the immune controls are the ones which had been previously immunized by the intravenous method. This experiment indicates that the bursa was infected in the unimmunized birds and was not infected in the immune controls. Evidence of this was further demonstrated on physical examination of the cloaca and the opening into the bursal orifice. On the third day after vaccination, the bursal orifice and sometimes the cloaca were inflamed and swollen in the unvaccinated birds, while these parts in the immune controls remained practically normal.

Also this experiment indicates that the virus was retained in the bursa of Fabricius of the unimmunized birds for five days after vaccination, before it began to disappear, and it was demonstrated in some of the birds up to the ninth day. The virus in the bursa of the immune controls apparently began to deteriorate at once and could not be demonstrated four days after inoculation.

Two weeks after all visible inflammation and swelling of the bursal orifice had ceased, the chickens were inoculated intratracheally with infectious laryngotracheitis virus and were found to be immune. Four controls inoculated at the same time contracted the disease and three died.

After it had been established that the bursa of Fabricius could be infected with the virus of infectious laryngotracheitis, and that the infection was apparently of sufficient duration to stimulate the production of immune bodies which reached the mucous membrane of the trachea, it was decided to immunize birds on a comparatively large scale, under laboratory conditions, and to determine the duration of immunity established by this method more fully, as well as to study any other complications which might arise. No special refinements were made in the preparation of the vaccine, except that the viruses used had been prepared by the Swift method (Gibbs, 1933a), and had killed chickens one month old in a week. This arbitrary standard seemed to be necessary, because it was observed in preliminary experiments that the bursa of Fabricius was not as easily infected as the larynx and trachea, so that any virus of diminished virulence might not produce

satisfactory immunity, but lead to erroneous conclusions in regard to the efficacy of the method.

The Vaccination of Roosters and Fowls

A mixed group of birds was available for this experiment, consisting of 12 roosters and 23 fowls. All of these birds had reached maturity and the bursa of Fabricius had completely involuted. The birds were placed in individual cages, and 27 of them inoculated in the bursal fold, while 8 controls were inoculated intratracheally. Eight of the inoculated birds came down with infectious laryngotracheitis in five days, which is about the average incubation period for fowls in production, and two of them died. Seventeen days after vaccination the birds were inoculated intratracheally with infectious laryngotracheitis virus, and all were found to be immune, except the controls. The controls contracted the disease and three died.

The surviving birds were held under observation for twenty-five days without any further indications of disease, except that one of the vaccinated fowls developed proctitis and inflammation of the oviduct, in addition to infection of the bursa of Fabricius. This condition led to prolapse of the oviduct. If this bird had been in a flock instead of in an individual cage, she would undoubtedly have been picked to death and the fatality charged to cannibalism without the real facts of the case being known.

The Vaccination of Pullets and Cockerels

In this experiment the pullets and cockerels were divided into four groups, according to age, 200 being vaccinated in the bursa of Fabricius while 82 were held in separate cages as controls. Fourteen days from the date of vaccination all of the birds, including the controls, were inoculated intratracheally with infectious laryngotracheitis virus. The results of this experiment are summarized in Table 10.

TABLE 10. — TESTS OF IMMUNITY OF PULLETS AND COCKERELS FOLLOWING BURSAL VACCINATION

Group	Age (Days)	Inoculated intratracheally after vaccination				Controls (intratracheal inoculation only)		
			Affected				Affected	
		Unaffected	Recovered	Died	Cannibalism	Unaffected	Recovered	Died
1	14	38	5	0	0	1	10	6
2	10	47	3	5	1	0	4	12
3	6	31	2	6	0	0	18	21
4	12	59	0	2	1	0	4	6
Totals		175	10	13	2	1	36	45

In Group 1, as indicated in Table 10, all of the vaccinated birds were protected, except five which apparently infected themselves soon after inoculation, and had mild attacks of infectious laryngotracheitis. It would appear natural for some of the birds to infect themselves before sufficient immunity was developed for protection, either by picking the vaccinated parts or from contaminated droppings on the floor. Of the 17 controls, 1 was found to be naturally immune, and 16 contracted the disease from which 10 recovered and 6 died. The birds were held for forty days after vaccination and none of them showed any after effects of the treatment.

Of the 55 vaccinated birds in Group 2, 9 contracted the disease after the usual incubation period for infectious laryngotracheitis in chickens, and of these 1 was killed as a result of cannibalism, 5 died naturally, and 3 recovered. When tested intratracheally for immunity, the 50 vaccinated birds living were found to be immune, but the 16 controls contracted the disease from which 12 died and 4 recovered. The surviving chickens were held for thirty-three days and appeared to be developing normally.

At necropsy 9 vaccinated chickens and 10 controls showed lesions of coccidiosis, and the mortality in both the vaccinated and control groups was confined almost entirely to the birds suffering from this complication. This experiment indicates that birds having chronic coccidiosis are not good risks for bursal vaccination with infectious laryngotracheitis virus.

In Group 3, 31 of the vaccinated birds were immune and 8 contracted the disease, of which 6 died and 2 recovered. All of the controls developed infectious laryngotracheitis and 21 died while 18 recovered. Lesions of coccidiosis were evident at necropsy in the 8 vaccinated birds showing symptoms of infectious laryngotracheitis and 11 of the controls. Once more the fact was forced upon the investigator that birds weakened by coccidiosis are not good subjects for treatment by this method.

Three days after vaccination two of the birds in Group 4 showed clinical symptoms of infectious laryngotracheitis and died. A pullet in which the cloaca became infected as well as the bursa, died of cannibalism. Of the 62 birds vaccinated, 59 did not show any symptoms of disease. All of the controls contracted infectious laryngotracheitis and six died, while four recovered.

Traumatic Cysts

Four of the vaccinated birds, one pullet and three cockerels, had traumatic cysts in the bursa of Fabricius similar to those shown in the photograph. The cysts looked like tapioca embedded in the mucous membrane, from which they readily shelled out, leaving small cavities. When placed in cold water the cysts swelled up and burst, liberating a sticky gelatinous mass, which gradually went into solution, while the covering membrane remained broken but insoluble in water. The gelatinous mass was precipitated from the solution by the addition of a few drops of 1 per cent acetic acid or alcohol and redissolved in 20 per cent NaOH solution, but it was not redissolved by an excess of acid. The covering membranes were not soluble in any of the reagents used. These tests indicate that the traumatic cysts consist largely of mucous.

The significance of these cysts is not fully realized at present. The vaccination must have had something to do with them for they have not been found in unvaccinated birds.

The Duration of Immunity

Fifty-six chickens from Group 4, immune to infectious laryngotracheitis at the time of placing in a colony house, were kept for ten months for studies on the duration of immunity. One of the cockerels died of avian paralysis before the tests were commenced. However, five months after vaccination 55 of the birds were inoculated intratracheally with infectious laryngotracheitis virus, and 6 of them came down with clinical infectious laryngotracheitis. Three of the infected birds died, three recovered, five developed laryngotracheal rales, and two proved to be chronic carriers. None of the 52 living birds were found to be harboring the

virus in the bursa of Fabricius, although the bursal fold was closed with adhesions in 2 of the roosters so that they could not be tested for the carrier stage. One pullet died before the experiment was closed. Necropsy revealed the bursal fold constricted so that the opening from the oviduct into the cloaca was obstructed, and the bird could not lay. Two completely formed eggs were found in the oviduct.

Bacteria in Tracheal Exudates Complicate Bursal Vaccinations

In order to study the importance of bacteria in bursal vaccinations, 36 chickens six weeks old were divided into three groups of 12 each. Group 1 was inoculated with Seitz-filtered infectious laryngotracheitis virus, Group 2 with streptococci isolated from the tracheas of chickens and fowls (Gibbs, 1933b), and Group 3 with staphylococci from the tracheas of normal fowls which showed pathogenic properties when the mucous membrane was injured as in infectious laryngotracheitis (Gibbs, 1930). The same degree of infection occurred in Groups 1 and 2, and in three of the chickens in Group 3, so that it was impossible to distinguish the bacterial from the virus inoculation or "take." It was concluded from this experiment that bacteria in the tracheal exudate may complicate vaccinations in the bursa of Fabricius and interfere with the determination of successful takes. For this reason it was felt that considerable care should be exercised in the selection and cultivation of tracheal exudate for vaccine.

In the routine preparation of infectious laryngotracheal exudate for vaccine, the virus should be filtered in order to free it from bacteria. It should always be prepared from chickens one month old, which have been hatched in incubators and reared under especially sanitary conditions away from all other birds.

The filtration of infectious laryngotracheitis virus presents some difficult problems. However, if a modification of Ward's (1928) method is used the virus should pass Seitz and Berkefeld filters more readily than if the exudate is triturated in physiological saline solution or yeast water alone. In applying the modified Ward method to the filtration of infectious laryngotracheitis virus, the exudates were ground up in mortars with fragments of Pyrex glass, and suspended in hormone broth. Before pouring the mixture into the filters the surfaces of the Seitz disks were covered with a layer of broken glass. Extra fragments of glass were not added to the Berkefeld filters because they could not be held in place before pouring in the exudate and starting the suction. The hormone broth is a modification of Huntoon's method, and it was prepared as follows:—

Four hundred grams of minced chicken heart free from fat, ten grams of peptone, and five grams of salt were boiled for fifteen minutes in one liter of water. The meat particles were removed by straining through cheesecloth, and the broth autoclaved at 15 pounds extra pressure for half an hour. It was allowed to stand over night in the ice box. The next morning the supernatant fluid was decanted off, 25 cc. to a flask, and autoclaved for 15 minutes.

Table 11 shows the results of this experiment with Seitz and Berkefeld V, N, and W filters, and indicates that hormone broth plus Ward's method of filtration is more efficacious than either physiological saline solution or yeast water alone. If this method of filtration had been known when the experiments on the intravenous and subcutaneous inoculation of infectious laryngotracheitis were made, the results might have been more encouraging. Discrepancies of this sort are to be expected in a project which has not passed out of the experimental stage.

TABLE 11. — FILTRATION OF INFECTIOUS LARYNGOTRACHEITIS VIRUS

Dilution of Filtrate	Saline				Yeast Water				Hormone Broth			
	S	V	N	W	S	V	N	W	S	V	N	W
1-10	0	0	0	0	0	+	0	0	+	+	+	0
1-25	0	+	0	0	+	+	0	0	+	+	+	+
1-50	+	+	0	0	+	+	+	0	+	+	+	+

Legend:—S - Seitz filter
V - Berkefeld V filter
N - Berkefeld N filter
W - Berkefeld W filter

CONTINUOUS CULTIVATION OF THE VIRUS IN THE BURSA OF FABRICIUS

This part of the project was designed to determine whether the virus of infectious laryngotracheitis could be continuously cultivated in the bursa of Fabricius or not, and if so, whether bacteria interfering with vaccinations could be eliminated or not. Furthermore, it was deemed important to study the immunizing properties of the viruses as they were being continuously cultivated, in the hope that they would become adapted to growth in this organ and lead to the discovery of a more satisfactory immunizing agent than has been found up to the present.

Accordingly, two viruses which had given the best results in previous bursal vaccinations were selected for this study. In each of these trials two chickens were inoculated in the bursa of Fabricius and the virus was transferred to the same organ of two other chickens every three days. At each transfer two control chickens were inoculated intratracheally with the same virus and the results recorded as indicated in Tables 12 and 13.

TABLE 12. — CONTINUOUS CULTIVATION OF VIRUS X IN THE BURSA OF FABRICIUS

Date	Bursa	Trachea	Result	Immunity
8/27/32	–	V-1204	Unaffected	+
	–	V-1205	Died	–
8/30/32	V-1206	V-1208	Unaffected	+
	V-1207	V-1209	Died	–
9/ 3/32	V-1210*	–	–	–
	V-1211*	–	–	–
9/ 6/32	V-1212	V-1214	Unaffected	0
	V-1213	V-1215	Unaffected	0
9/ 9/32	–	V-1216	Recovered	+
	–	V-1217	Recovered	+
9/12/32	V-1220	V-1222	Unaffected	0
	V-1221	V-1224	Died	–
9/15/32	V-1225	V-1227	Died	–
	V-1226	V-1228	Died	–
9/19/32	V-1229	V-1231	Died	–
	V-1230	V-1232	Recovered	+
9/22/32	V-1233	V-1235	Unaffected	0
	V-1234	V-1223	Unaffected	0

*Died

TABLE 13. — CONTINUOUS CULTIVATION OF VIRUS Y IN THE BURSA OF FABRICIUS

Date	Bursa	Trachea	Result	Immunity
10/18/32	–	V-1236	Died	–
	–	V-1237	Died	–
10/24/32	–	V-1238	Died	–
	–	V-1239	Recovered	+
10/25/32	V-1242	V-1244	Unaffected	+
	V-1243	V-1245	Died	–
10/28/32	V-1249	V-1251	Unaffected	+
	V-1250	V-1252	Died	–
10/31/32	V-1255	V-1259	Died	–
	V-1256	V-1260	Died	–
11/ 3/32	V-1257	V-1262	Died	–
	V-1258	V-1264	Died	–
11/ 6/32	V-1261	V-1266	Died	–
	V-1263	V-1268	Died	–
11/ 9/32	V-1265	V-1270	Died	–
	V-1267	V-1296	Died	–
		V-1297	Died	–
11/12/32	V-1269	V-1273	Died	–
	V-1271	V-1275	Died	–
11/17/32	V-1272	V-1277	Died	–
	V-1274	V-1279	Unaffected	+
11/19/32	V-1276	V-1281	Unaffected	+
	V-1278	V-1283	Recovered	+
11/23/32	V-1280	V-1285	Unaffected	0
	V-1282	V-1287	Died	–
11/26/32	V-1284	V-1289	Unaffected	0
	V-1286	V-1291	Died	–
11/29/32	V-1288	V-1293	Unaffected	0
	V-1290	V-1295	Died	–
12/ 2/32	V-1292	V-1297	Recovered	+
	V-1294	V-1299	Died	–
12/ 6/32	V-1296	V-1301	Died	–
	V-1298	V-1303	Died	–
12/ 9/32	V-1300	V-1305	Unaffected	+
	V-1302	V-1307	Recovered	+
12/12/32	V-1304	V-1308	Recovered	+
	V-1306	V-1309	Died	–

Virus X, Table 12, was not very satisfactory because it was lost twice, once in chickens V-1212 and V-1213, and again in chickens V-1233 and V-1234. Virus Y, Table 13, was cultivated continuously in the bursa of Fabricius for 58 days without loss of virulence, or change in immunizing properties. The bacterial flora was different than in viruses from the respiratory tract. The bacteria were of intestinal origin and did not influence the results in vaccinations, but further study is needed to clear up this point. This study was not continued further at this time because no advantage was obtained in cultivating the virus exclusively in the bursa of Fabricius, since a better check on the virulence was maintained when the chickens were inoculated intratracheally.

However, in selecting a virus for vaccine in the future, virus Y will be chosen rather than virus X, because of its uniform results in this experiment.

CLOACAL VERSUS BURSAL VACCINATION

Forty chickens, three and one-half months old, were divided into two groups of twenty each. Group 1 was inoculated in the cloaca and Group 2 in the bursa of Fabricius. In Group 1, 8 of the chickens developed mild inflammation of the cloaca, which indicated 40 per cent successful takes; while 18, or 90 per cent, of those inoculated in the bursa of Fabricius showed definite indications of takes. Two chickens from each group contracted infectious laryngotracheitis and died. When tested for immunity fourteen days later, 10 of the chickens in Group 1 contracted the disease and 6 died, while all of the 18 living chickens in Group 2 resisted infection.

This experiment indicates that the number of takes is greater when the bursa of Fabricius is inoculated than then the cloaca is swabbed with the same virus in the same manner, and the resulting degree of immunity is greater in the former than it is in the latter case.

DISCUSSION

In attempting immunization in infectious laryngotracheitis the object should be to produce an immunity at least as good as that which follows the disease when naturally contracted. At present this can not be accomplished artificially. Since birds infected in the larynx and trachea are liable to die of asphyxia, due to plugging of the respiratory tract with pseudomembrane, the infection should be kept from this system, unless partial immunity has been previously produced by means of properly filtered tracheal exudate or hyperimmune serum. Laryngotracheitis is primarily a disease of the mucous membranes and infection is not induced by inoculation of the virus into the subcutaneous tissues or blood stream. However, when a relatively large dose of the virus is released in the blood stream, the infectious agent may be carried to the larynx and trachea and a natural attack result. On the other hand, when the virus is introduced into the blood stream in relatively small quantities over a comparatively long time, active immunity is produced. It seems to make little difference whether the small quantities are continuous, as they probably are in the bursa of Fabricius infection, or intermittent as in intravenous inoculation.

Naturally acquired immunity in infectious laryngotracheitis is permanent, while artifically acquired immunity is relative and appears to depend upon the severity of the reaction. Hence the introduction of filtered tracheal exudates into the blood stream, or the inoculation of a mucous surface outside of the trachea such as the bursa of Fabricius, stimulates various degrees of active immunity. The inoculation of hyperimmune serum into the blood stream produces passive immunity only, because the antigen is not present, and the tissues of the bird are not stimulated to produce antibodies. It is impossible to control the reaction in any of the methods suggested for the immunization of birds against infectious laryngotracheitis, because a standard vaccine has not been produced, and in spite of the arbitrary standard suggested in this bulletin for inoculation in the bursa of Fabricius, the danger of spreading the infection where it does not already exist is involved.

Birds weakened, as in coccidiosis, are liable to develop acute infectious laryngotracheitis when vaccinated in the bursa of Fabricius and relatively large numbers die. The simultaneous vaccination of birds against infectious laryngotracheitis and chicken pox was not attempted in these studies, because the experiments were conducted in the laboratory, and it was not considered expedient to make the two tests under such limitations, for fear that the results might

lead to erroneous conclusions. This point should be made clear by carefully controlled experiments under range conditions, and moreover, further studies of infectious laryngotracheitis are needed to determine the practical value of the laboratory methods and immunological theories advanced herein under field conditions, without complication with chicken pox or any other disease which might lessen vitality.

In vaccinating a large number of birds, various degrees of reactions are bound to occur. Some cases will be so mild that only temporary immunity results, while others will respond abnormally and develop a disease so severe that some will die and carriers are produced in a few of those that recover. However, evidence is lacking to show that sufficient virus passes into the blood stream from the infected bursa of Fabricius to be responsible for clinical cases, although it has been demonstrated that birds do infect themselves after vaccination by picking and rubbing the affected parts, and probably indirectly from the virus in the droppings. Thus the danger of creating fresh centers of infection, through the agency of vaccinated birds and carriers, is obvious, in spite of the fact that most of the birds may respond normally and be satisfactorily immunized against the disease.

SUMMARY

1. In order to be acceptable to the majority of poultrymen, treatments for infectious laryngotracheitis must be cheap, easy to administer, and fairly effective.

2. Since the intravenous and subcutaneous methods of stimulating immunity did not measure up to this standard, they are not recommended for field practice.

3. However, the intravenous and subcutaneous studies were conducted under controlled laboratory conditions and the following fundamental immunological points discovered:—

(a) Birds can be immunized against infectious laryngotracheitis by introducing small doses of virus intermittently into some portion of the body other than the respiratory tract.

(b) The virus is carried by the blood and may stimulate the production of immune bodies in all tissues directly in touch with the vascular system.

(c) Large quantities of virus released into the blood stream at once may be carried to the respiratory tract and lead to the development of active symptoms.

4. The inoculation of the bursa of Fabricius appeared to be the most satisfactory way of utilizing the immunological discoveries brought out in this study for immunizing birds against infectious laryngotracheitis.

5. The best time to vaccinate appeared to be between three and four months of age, or when the bursa of Fabricius had reached its greatest development.

6. Only birds in the best of health are suitable for vaccination against infectious laryngotracheitis.

7. The significance of certain traumatic cysts, blow-outs, and adhesions found in the bursa of Fabricius and adjacent parts of some of the birds after vaccination is not understood, in view of the fact that special care was taken to avoid rough handling.

8. Special care should be exercised in selecting and cultivating tracheal exudate for bursa of Fabricius vaccination in order to exclude pathogenic bacteria and viruses other than the causative agent in infectious laryngotracheitis.

9. Infectious laryngotracheitis tracheal exudates desiccated and preserved by the modified Swift method maintain their virulence for several months.

10. Final judgment should be withheld on the bursa of Fabricius vaccination until carefully controlled experiments are completed to determine its practical value under range conditions, and the duration of immunity in fowls in heavy production.

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Publication of this Document Approved by Commission on Administration and Finance. 3M-5-'33 No. 8464.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 296 MAY, 1933

Effect of Manufacturing and Preserving Processes on the Vitamins of Cranberries

By Paul D. Isham and Carl R. Fellers

Cranberries are an important crop in Massachusetts. Nearly all of them are processed in some way before they are consumed. This study was undertaken to determine the effect of various methods of processing on their nutritive value.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

EFFECT OF MANUFACTURING AND PRESERVING PROCESSES ON THE VITAMINS OF CRANBERRIES[1]

By Paul D. Isham, Research Fellow, and Carl R. Fellers, Research Professor of Horticultural Manufactures

PURPOSE

A comprehensive investigation of the vitamin content of the American cultivated cranberry, *Vaccinium macrocarpon*, was undertaken to include several varieties, seasons, storage conditions, and manufactured products such as evaporated, frozen, and canned cranberries. This is the first of a series of studies planned to investigate the effect of manufacturing methods on the nutritive value of fruits and vegetables. Only limited data are available on this general subject. Results obtained in the present investigation show the necessity of actually determining the changes which may occur in a fruit during storage, processing, and preservation.

INTRODUCTION

Since cranberries are a very important crop in Massachusetts, data relative to their vitamin content and the effect of storage, home cooking, and commercial manufacturing processes on these vitamins are very desirable. Approximately 300,000 cases or 10,000,000 pounds of cranberry sauce are produced each year. Since a pound of cranberries makes about 2.6 pounds of sauce, the cranberries used for commercial canned sauce manufacture represent close to 40,000 barrels. However, most of the fruit is consumed as sauce prepared in the home. The per capita consumption of cranberries in the United States is 0.54 pound. Cranberries are harvested in September and October and may be found on the market until late winter.

Because of confusion in nomenclature in published articles on the cranberry, and to clarify several literature citations in this paper, a very brief discussion of the botanical relationships of the cranberry is given. The common, large, cultivated American cranberry so widely consumed in this country is known as *Vaccinium macrocarpon*. European references to cranberries generally refer to other species. Most important of these is *V. Vitis-Idaea*, also known as the mountain or rock cranberry (U.S.), cowberry, foxberry (Gt. Britain, Canada), Preisselbeere (Germany), tyttebaer (Norway), lingon berry (Sweden), Kroesa (Denmark), and partridge berry (Newfoundland). This species grows on upland and rocky places rather than in swamps. The other species, *V. Oxycoccus*, is known as the moss, bog, or swamp cranberry, and also as the small or speckled cranberry. The fruit and vine of this species are smaller than either *V. macrocarpon* or *V. Vitis-Idaea*.

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[1] Part of a thesis submitted by the senior author to the faculty of the Graduate School, Massachusetts State College, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

The financial aid and encouraging interest of the American Cranberry Exchange of New York are gratefully acknowledged. Thanks are likewise due to the Birdseye Laboratories, Gloucester, for packing, freezing and storing fruit for the freezing experiments; and to M. L. Urann of South Hanson, J. C. Makepeace of Wareham, Dr. H. J. Franklin of the Cranberry Station, East Wareham, Hills Brothers Company of New York, and Sardik Laboratories, Inc. of New York, for furnishing fruit and other products.

HISTORICAL

No thorough investigation of the vitamin content of cranberries has been reported. In fact, no work has been reported on vitamins A,B,D, and G. MacLeod and Booher (22) reported the American cranberry as being a poor source of vitamin C. However, this conclusion is open to criticism, first, because the cranberries had been in storage for seven or more months and, as will be demonstrated in this paper, had undoubtedly lost much of their original vitamin C content; and second, because the experimental animals did not consume their full portion of fruit plus basal ration. Naeslund (28) investigated the vitamin C content of *V. Vitis-Idaea* in Norway and found them to be weakly antiscorbutic. He estimated the protective portion of fruit or freshly expressed juice to be more than 50 grams, with no difference in potency between the whole berry and its expressed juice. Using the same fruit, Laland (21) was unsuccessful in his attempts to isolate narcotine, believed by Rygh and his coworkers (31,32,33) to be the precursor of vitamin C. However, Dalmer and Moll (9) and Brüggemann (6) were unable to verify Rygh's results; and recently Svirbely and Szent-Györgyi (40), and also King and Waugh (18) have proved beyond question that vitamin C is closely related to or identical with hexuronic acid.[2]

After the completion of the vitamin C studies reported in this paper, a recent Russian investigation on *V. Oxycoccus* came to our attention. Bogoliubova (3) found that 2.5 grams of these wild cranberries, after storage for three months near the freezing point, fully protected guinea pigs from scurvy during a seven weeks' test period. However, cranberries which had lain under snow all winter or which had been alternately frozen and thawed, showed no protective action. Similarly, dried or fermented cranberries lost their vitamin C potency. She believes that cranberries are an important antiscorbutic in all northern countries and states that the value of cranberries for the treatment of scurvy in Russia was known as early as 1848. Mention is made that sailing vessels used cranberry juice as an antiscorbutic many years ago.

Bogoliubova also noted the absence of xerophthalmia in her guinea pigs, and since the oat diet was deficient in vitamin A, concluded that cranberries contained some of this vitamin. However, no data were presented.

The resistance of vitamin C to heat and oxidation is materially increased by high acidity, and the cranberry is characterized by a high acidity which averages about 2.3 per cent (calculated as citric acid). According to Nelson (29), the fixed acids are 88 per cent citric and 10 per cent malic. Mason (24) detected benzoic acid in the cranberry; this finding was verified by Griebel (17), and also in this laboratory where it was found that the benzoic acid content of 25 varieties ranged from 0.027 to 0.098 per cent. It is probable that the good keeping qualities of fresh and preserved cranberries are in part due to the presence of free or combined benzoic acid. The presence of quinic acid in cranberries was presumed by Blatherwick and Long (2) and by Quick (30). Kohman and Sanborn (20), Morse (27), and Fellers, Redmon and Parrott (15), have gathered further positive evidence of the presence of 0.38 to 1.03 per cent of quinic acid in cranberries. Unlike benzoic acid, quinic acid has no significant antiseptic properties against microorganisms.

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[2]Recent investigations by Hahn (Ztschr. Untersuch. Lebensmtl. 61:369-411, 515-611, 1931) show that raw or cooked mountain cranberries are very poor sources of vitamin C.

The red pigment of the *V. Vitis-Idaea* cranberry has been proved by Willstätter and Mallison (41) to be the anthocyan idaein, hence is unrelated to vitamin A. By using Willstätter's technic, Morse (26) obtained 2.1 grams of idaein from 22 kilograms of American Early Black cranberries.

Of possible significance in vitamin C retention is the gas content of cranberries. The oxygen content varies from practically zero to 14 per cent depending upon the freshness of the fruit and storage conditions. A considerable percentage of carbon dioxide is always present in the tissues and voids of the fruit.

SOURCE AND PREPARATION OF SAMPLES

Fresh and Frozen Cranberries

In general the fruit was obtained from the Massachusetts Cranberry Station at East Wareham in 1930, 1931, and 1932, though samples were also furnished by the A. D. Makepeace Company, Wareham, the United Cape Cod Cranberry Company, South Hanson, and the American Cranberry Exchange, New York, N. Y.

Cranberries were harvested in September and October and held in cold storage at 40° F. in 50-pound, one-half barrel, ventilated boxes. In general, the fresh fruit and products were assayed for vitamin C within four months from the harvesting date, which corresponds to the active commercial marketing season. Early Black, Howes, and Perry Red varieties were used. The first two are the most important commercial varieties in Massachusetts and represent early and late maturing varieties. In order to determine the effect of storage upon vitamin C content, fresh cranberries from the same lot were stored at 40°, 15°, 0°, and -15° F. Thus the effect of freezing was also ascertained. The lots held at 0° and -15° F. were frozen at -30° F., in small waxed-paper cartons holding one-half pound of cranberries, by the Birdseye Multiplate Freezer. All frozen cranberries were not defrosted until just before feeding. The frozen samples included whole, sliced and sweetened, and crushed and sweetened berries, and a strained product. The samples held at 15° and 40° were in the bulk, 50-pound boxes.

The freezing of cranberries as a means of preservation has been carried on in this department since 1927 and has been practiced by the canners for several years as a means of extending the canning season. Quick-freezing of whole cranberries for the retail trade has been conducted on a limited scale since 1931.

Dehydrated Cranberries

Commercially dehydrated whole cranberries, usually called "evaporated" by by the trade, were examined for vitamin activity. These berries were pricked 20 to 30 times with steel needles to allow evaporation of moisture and dehydrated for 8 to 12 hours at temperatures of 120° to 150° F. in forced-draught dryers. The moisture content is normally less than 5 per cent. One hundred pounds of fresh fruit yield about 10 pounds of dehydrated cranberries.

By grinding this product a fine red powder was obtained which served as the basis of the tests for vitamins A, B, D, and G.

Cranberry film is a dehydrated cranberry product prepared by boiling fresh cranberries in a small amount of water for two to three minutes, hot pulping, and immediately drying in a thin film on a rotating steam-heated drum dryer. The film resembles crepe paper. One hundred pounds of fresh cranberries yield about 12.3 pounds of film. The film can be used in the preparation of cranberry sauce.

Film samples were pulped and dried in air, and in nitrogen gas. The film was prepared for feeding by mixing with water in definite concentrations. In this way, desired amounts were accurately administered by pipette.

Cranberry Juice

Cranberry juice or cocktail has recently become of some commercial importance. The juice possesses a very deep red color and a characteristic flavor. It is particularly suitable for use as a blender in punches and similar beverages.

Cranberry juice was prepared by two methods and is designated "cold-pressed" and "heat-extracted." The cold-pressed juice was prepared by grinding the fresh cranberries in a food chopper and expressing the juice by means of a large hand press. The yield of juice averaged 6 gallons per barrel (100 pounds) of cranberries.

The heat-extracted juice was prepared by boiling 100 pounds of cranberries with 6.5 gallons of water for 8 to 10 minutes. The pulpy mass was cooled to room temperature and pressed. The yield was about 8 gallons per barrel of fruit. The sweetened juice was prepared by adding sufficient sugar to yield a soluble solids content of 50 per cent. Both fresh and pasteurized raw pressed juices were examined for vitamin C. Pasteurization was effected by a heat treatment of 20 minutes at 160° F. of the juice sealed in small tin cans or one-half pint bottles. One series of samples in the bottles was sealed under a partial vacuum of 25 inches of mercury.

Cranberry juice cocktail was prepared according to the recipe recommended by the American Cranberry Exchange (1). One quart of cranberries was boiled with one quart of water until soft, then strained through a cheese-cloth, the juice brought to boiling, two-thirds cup of sugar added, and the boiling continued for two minutes. This juice was filled into sterile jars, sealed, and immediately cooled.

Commercially, cranberry juice cocktail is prepared by grinding the fruit, cooking with water until soft, adding a pulp filter aid, centrifuging, making up filtrate to a volume representing two parts water to one of fruit, adding sugar to 15° Brix, heating to 180° F., and immediately filling into sterile glass containers and sealing. Frozen cranberries are preferred to fresh in the manufacture of this product.

Cranberry Sauce

Cranberries are normally consumed in the form of a cooked sweetened sauce, either strained or unstrained. The sugar content of the sauce varies from 41 to 48 per cent.

Whole-fruit, unstrained cranberry sauce was prepared according to the widely used "Ten Minute" Cranberry Sauce (1) recipe of the American Cranberry Exchange. The recipe calls for 1 pound of cranberries, 2 cups of water, and 1½ to 2 cups of sugar. The sugar and water are boiled together for 5 minutes, then the cranberries are added and boiled without stirring until the skins pop open. This usually requires about 5 minutes. This material was sealed hot in small jars and immediately cooled. Investigations on canned foods (10, 11) have shown that practically no deterioration of the vitamin C content occurs in the can even over a period of several years. All sauce was kept in the refrigerator at 33° F., and no jar was used for feeding after being open 24 hours. The surface of the material in the opened jars was kept covered with paraffin. Just prior to feeding, the sauce was pressed through a fine screen to allow its being administered by

pipette. This process is the one referred to as cold pulping or cold straining in this paper.

It was brought to our attention that cranberry sauce is often prepared in the home by cooking cranberries in water and then adding the sugar. Whole-fruit sauce was therefore prepared in this manner and treated as was the "Ten Minute" cranberry sauce.

Commercially prepared whole-fruit cranberry sauce was also examined for its vitamin C content. This material was manufactured by a method practically identical to that specified for "Ten Minute" cranberry sauce.

The strained cranberry sauce was prepared in several ways. In each case, however, the berries were pulped while at boiling or near boiling temperatures without any special precautions to prevent oxidation. Strained "Ten Minute" cranberry sauce was prepared and immediately sealed in small jars. Other strained sauce was prepared in small amounts according to commercial practice. The cranberries were boiled for two or three minutes in water, pulped while hot to remove seeds and skins, the sugar added, and the mixture concentrated in a jelly kettle to a jelly test (216° to 218° F. or 43 per cent soluble solids by refractometer). The hot liquid sauce was filled into cans and sealed without further heat treatment. As an average, 1 pound of cranberries will yield 2.6 pounds of sauce. Several brands of commercially packed strained sauce were likewise assayed.

Cranberry Jelly and Candy Filling

Cranberry jelly was prepared according to the recipe of the American Cranberry Exchange (1). This calls for 8 pounds of cranberries, 12 cups of water, and 2½ pounds of sugar. The cranberries are cooked in the water until soft, and the juice strained off through a jelly bag. The juice is measured and heated to boiling, 1 cup of sugar added for each 2 cups of juice and stirred in until dissolved, and the whole boiled briskly for 5 minutes. It is then poured into glasses and covered with paraffin. Small glasses were used, and a new one taken for each feeding.

The cranberry content of cranberry candy as such was too low to allow feeding in amounts sufficient to afford protection to the animals. Therefore, the cranberry material as it is mixed into the candy was obtained and used for feeding tests. This material was nothing other than finely chopped cranberries. It was stored, sealed in large jars, in the refrigerator at 33° F. Just prior to feeding, a suitable quantity was pressed through a fine screen while still cold, and this material used for feeding.

EXPERIMENTAL RESULTS

Vitamin C

The Sherman, LaMer, and Campbell (34) method was used, with the exception that the amounts fed were proportioned to the weight of the guinea pigs; i. e., a 400-gram animal was fed 4/3 as much as one weighing 300 grams. The animals were all young and healthy, weighed between 280 and 325 grams, and were housed in individual cages. The basal ration consisted of 58 per cent equal parts of rolled oats and wheat bran, 30 per cent of vitamin C-free baked milk powder, 10 per cent butter fat, and 1 per cent each of cod-liver oil and salt. This basal ration and water were kept before the animals at all times.

Normally three guinea pigs were used at each feeding level. At the end of the feeding period all animals were chloroformed and carefully examined for lesions of

scurvy. Negative controls died in from 26 to 36 days with an average Sherman scurvy score of 19.

Because of the dislike of guinea pigs for cranberries, it was necessary in all the vitamin C assays to express the juice and finely divided pulp from fresh, frozen, and soaked evaporated cranberries, and to force-feed the animals by pipette. All samples were freshly prepared daily immediately before feeding. In cooked and canned cranberries, the pulp freed from skins was likewise fed by pipette. In order to be assured that each animal received its full share, weighings were made before feeding and several times during the feeding process until the required weight was reached.

The results obtained on vitamin C are presented in Tables 1 to 5 and Figures 1 to 5. In general, these data are largely self-explanatory and require only brief discussion. Only certain representative results are shown in the curves, but all the data are summarized in the tables.

TABLE 1. — VITAMIN C CONTENT OF RAW CRANBERRIES

Variety	Year	Storage period	Number of guinea pigs	Amount fed daily	Gain or loss in weight average	Survival period average	Scurvy score average
		Months		*Grams*	*Grams*	*Days*	
Early Black	1930	2 to 5	5	10	+153	90	0
	1930	2 to 5	5	5	+134	90	0
	1930	2 to 5	2	3	+199	90	2
	1931	1 to 4	3	4	+165	90	1
	1931	7 to 8	3	10	−111	29	9
	1931	7 to 8	3	5	−112	31	12
	1932	3 to 6	3	4.5	+183	90	0, 0, 3
	1932	3 to 6	3	3.5	+30	90	4
Howes	1930	2 to 5	3	4	+123	90	0
	1930	2 to 5	3	2	+4.5	90	7
	1930	2 to 5	3	1	−58	42	12
	1930	9 to 11	3	10	+176	90	2
	1931	4 to 7	2	5	+130	90	6
	1931	4 to 7	2	3	−35	87	13
Perry Red*	1932	3 to 5	3	4.5	+290	60	0
	1932	3 to 5	3	3.5	+169	60	0, 0, 1

*Supply exhausted at 60 days.

Fresh and Frozen Cranberries

Several significant deductions can be drawn from Table 1 and Figure 1. Fresh cranberries of Early Black, Howes, and Perry Red varieties are very good sources of vitamin C, the minimum protective portion being close to 4 grams. There appears to be but little variation in vitamin C content due to differences in season or variety. For example, Early Black and Perry Red varieties differ greatly botanically, yet show similar vitamin C activity. The cranberry thus contains one-third to one-half as much vitamin C as the orange or tomato and is comparable with such foods as blueberries (14), pineapple (25), peaches (19), and some varieties of apples (12, 5).

Figure 1

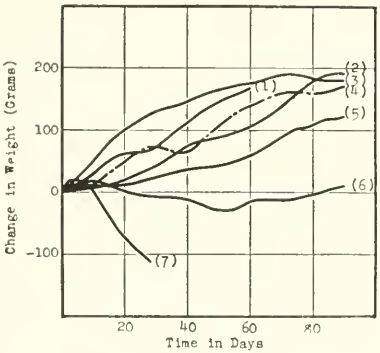

Figure 2

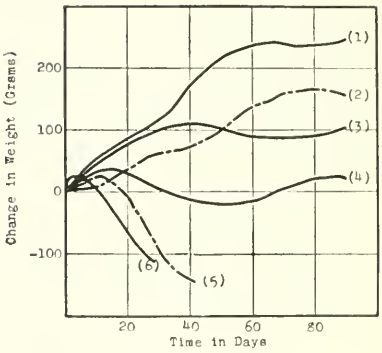

Figure 1. — Influence of Variety and Season on the Vitamin C Content of Cranberries

	Variety	Year	Grams fed daily	Scurvy score
1	Perry Red	1932	3.5	0
2	Early Black	1931	4	1
3	Early Black	1932	4.5	1
4	Early Black	1930	3	2
5	Howes	1930	4	0
6	Howes	1930	2	7
7	Basal Ration only			19

Figure 2. — Effect of Storage Temperature on the Vitamin C Content of Cranberries

	Storage Months	°F.	Grams fed daily	Scurvy score
1	7 to 9	15	5	0
2	2 to 4	40	4	1
3	7 to 9	0	5	0
4	9 to 11	15	10	12
5	7 to 8	40	10	9
6	Basal Ration only			19

From a study of Tables 1 and 2, it is evident that cranberries gradually lose vitamin C during storage at 40° F. There was little loss in Early Blacks or Howes stored under 3 months. After 4 to 6 months the loss was approximately 20 per cent; after 7 to 10 months, the loss became still greater — possibly 60 to 70 per cent in some cases. Howes keep better than Early Blacks, and this better keeping quality is reflected in better retention of vitamin C in storage. These results serve to explain why MacLeod and Booher (22) found little or no vitamin C in cranberries. Their samples had been in storage for 7 to 11 months, and the highest level fed was only 5 grams — an amount entirely insufficient to protect animals from scurvy after so long storage.

TABLE 2. — EFFECT OF STORAGE TEMPERATURE ON THE VITAMIN C CONTENT OF EARLY BLACK CRANBERRIES

Description of sample	Storage period	Storage temperature	Number of guinea pigs	Amount fed daily	Gain or loss in weight average	Survival period average	Scurvy score average
	Months	°F.		*Grams*	*Grams*	*Days*	
Whole fruit	2 to 4	40	3	4	+165	90	1
	7 to 8	40	3	10	−111	29	9
	7 to 8	40	3	5	−112	31	12
	9 to 11	15*	3	10	+22	90	12
	7 to 9	0	2	10	+122	90	0
	7 to 9	0	2	5	+102	90	0
	7 to 9	−15	2	10	+213	90	0
	7 to 9	−15	2	5	+246	90	0
†Crushed	7 to 9	0	2	10	+106	90	0
	7 to 9	0	2	5	+27	90	3
‡Sliced	7 to 9	0	2	10	+512	90	0
	7 to 9	0	2	5	+61	90	4.5

*Known to have been thawed and refrozen at least once.
†Frozen with added sugar — 10 g. = 7.5 g. cranberries; 5 g. = 3.8 g. cranberries.
‡Frozen with added sugar — 10 g. = 6.7 g. cranberries; 5 g. = 3.3 g. cranberries.

It is apparent from Table 2 and Figure 2 that the retention of vitamin C during storage is dependent on the storage temperature. Cranberries stored at −15° and 0° F. suffered no significant loss. Unfortunately, the cranberries in storage at 15° F. were allowed to thaw and then refreeze at least once during the storage period of 9 to 10 months. This probably explains the excessive loss of vitamin C at this temperature. However, even these cranberries retained at least twice as much vitamin C as those stored at 40° F. for the same period. The crushed and sliced cranberries to which sugar was added retained all their original vitamin C during storage at 0° F. Solidly frozen cranberries, therefore, retain fully their original antiscorbutic properties.

Dehydrated Cranberries

The vitamin C content of dehydrated cranberries, shown in Table 3 and Figure 3, varies according to the method of manufacture. Evaporated cranberries contained practically no vitamin C, while the cranberry film [3] prepared in an at-

[3] The name of the manufacturer will be furnished upon request.

mosphere of nitrogen suffered but a slight decrease in antiscorbutic activity. The dried film itself was fully protective at the estimated low level of 0.7 gram, equivalent to about 8.4 grams of fresh cranberries. This represents a loss of about 35 per cent. Film manufactured by the same process with no effort to exclude oxygen lost 65 to 70 per cent of the vitamin C.

TABLE 3. — VITAMIN C IN DEHYDRATED CRANBERRIES

	Number of guinea pigs	Amount fed daily	Fresh fruit equivalent	Gain or loss in weight average	Survival period average	Scurvy score average
		Grams	*Grams*	*Grams*	*Days*	
Evaporated cranberries	3	0.83	8.3	−110	31	13
	3	42	4.2	−88	31	16
Cranberry film (pulped and dehydrated in air)	2	2	24	+164	90	0
	2	1	12	+3	90	4
Cranberry film (pulped and dehydrated in nitrogen)...	3	1.5	18	+118	30*	
	3	1.0	12	+333	90	0
	3	.5	6	+119	90	3

*Discontinued.

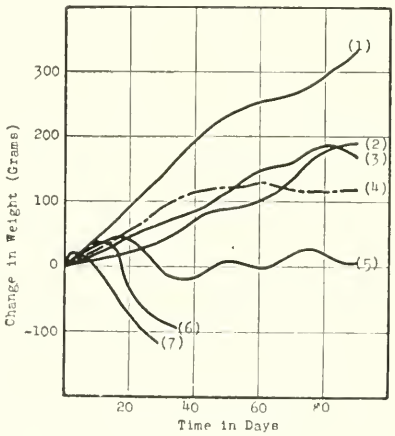

Figure 3. — Vitamin C Content of Dehydrated Cranberries

	Product tested	Grams fed daily	Fresh fruit equivalent *Grams*	Scurvy score
1	Cranberry film prepared under nitrogen	1	5.4	0
2	Raw cranberries	4	4	0
3	Cranberry film prepared under air	2	10.8	0
4	Cranberry film prepared under nitrogen	.5	2.7	3
5	Cranberry film prepared under air	1	5.4	4
6	Evaporated cranberries	.83	8.3	13
7	Basal Ration only			19

Cranberry Juice

Cold-pressed cranberry juice was equal to the fruit in vitamin C content and when boiled in an open vessel for two minutes showed no loss. However, when either this or heat-extracted juice was bottled and pasteurized, there was very little retention of the vitamin C. This was true regardless of whether the juices were sweetened or unsweetened, or sealed in the bottles with or without vacuum. The two cranberry-juice cocktails which were examined were manufactured by heat extraction methods and likewise showed almost complete loss of vitamin C. A cocktail was prepared from cold-pressed juice and pasteurized, but this was likewise devoid of any appreciable antiscorbutic property.

TABLE 4. — VITAMIN C IN TREATED CRANBERRY JUICE AND COCKTAIL

Method of preparation	Number of guinea pigs	Amount fed daily	Fresh fruit equivalent	Gain or loss in weight average	Survival period average	Scurvy score average
		Grams	*Grams*	*Grams*	*Days*	
Cold-pressed juice						
Boiled 2 minutes	3	8	8	+191	90	0
	3	4	4	+192	90	0
	3	4*	4	+188	90	0
Pasteurized 20 minutes at 160°F	3	6	6	−113	37	13
	5	4	4	−102	38	15
	3	3	3	−73	35	16
Sweetened and pasteurized	5	8	4	−169	40	10
Vacuum sealed and pasteurized	3	6	6	−140	36	12
Heat-extracted juice						
Pasteurized	3	6	6	−102	37	16
	3	3	3	−98	34	16
Vacuum sealed and pasteurized	3	6	6	−118	19	9
Cranberry juice cocktail						
Exchange's recipe	3	10	3.4	−165	46	15
	3	5	1.7	−162	33	15
Exchange's recipe, modified:						
Hot pressed	2	10	3.4	−134	33	15
Cold pressed	2	10	3.4	−80	32	18
Commercial	3	20	6.9	−91	40	15
	3	15	5.2	−131	26	12
	5	10	3.4	−117	34	14

*Plus 5 g. sugar.

These numerous examinations show that both cold-pressed and heat-extracted cranberry juices when bottled, sealed, and pasteurized retain very little vitamin C. It is possible that methods designed to avoid oxidation would be of value.

Cranberry Sauce

Since the greater proportion of cranberries are consumed in the form of cranberry sauce, a more extensive investigation of this product was carried out. The data are presented in Table 5 and Figure 5.

TABLE 5. — VITAMIN C CONTENT OF CRANBERRY SAUCE

Method of Preparation	Number of guinea pigs	Amount fed daily	Fresh fruit equivalent	Gain or loss in weight average	Survival period average	Scurvy score average
		Grams	*Grams*	*Grams*	*Days*	
Whole-fruit "Ten Minute" sauce	3	14*	8	+279	90	0
	4	7*	4	+82	90	2
	4	20	7	+42	90	2?
	7	10	3.5	+90	90	5
Whole-fruit sauce (sugar added last)	2	10	3.5	−99	90	3
Hot-strained "Ten Minute" sauce	3	8*	4.5	−49	52	9
	3	20	7	+39	83	10
	3	15	5.3	−92	33	8
	3	8	2.8	−134	38	10
Hot-strained sauce	5	20	7	−70	25	11
	5	10	3.5	−164	38	18
	5	8	2.8	−62	57	17
M. S. C. canned strained sauce	5	26	9.1	−146	31	16
	5	13	4.6	−148	31	15
Commercial strained sauce 1	2	20	7	−50	29	12
	2	10	3.5	−61	33	13
Commercial whole-fruit sauce 1 (1930)	3	20	7	−58	38	14
	3	10	3.5	−23	35	16
Commercial whole-fruit sauce 1 (1931)	3	12	4.2	−60	65	5
Commercial strained sauce 1, vacuum packed	2	20	7	−58	50	17
	2	10	3.5	−52	52	15
Commercial strained sauce 2	2	20	7	−73	37	17
	2	10	3.5	−48	33	16
Strained sauce, frozen and stored 9 months at 0°F.	2	12	9.6	−16	70	9
	2	6	4.8	−128	62	14
Jelly (Exchange's recipe)	3	12	6	−156	40	12
Cranberry candy filling	2	10	10	−80	36	16
	2	6	6	−157	35	14
	2	5	5	−103	47	18
	2	3	3	−122	36	15

*Made without sugar.

Figure 4

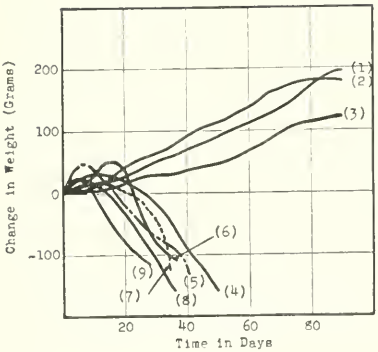

Figure 5

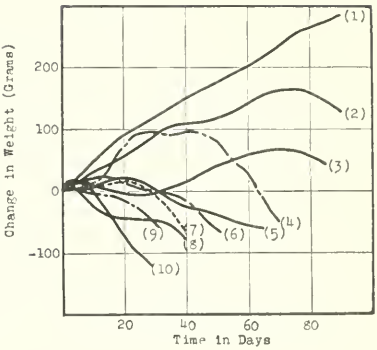

Figure 4. — Vitamin C in Cranberry Juice Prepared by Different Methods

	Method of preparation	Grams fed daily	Fresh fruit equivalent *Grams*	Scurvy score
1	Cold-pressed, boiled 2 minutes	4		0
2	Cold-pressed, boiled 2 minutes, plus 5 grams sugar	4		0
3	Cold-pressed, untreated	4		0
4	Cranberry juice cocktail (1)	10	3.4	15
5	Cold-pressed, vacuum packed, pasteurized	6		12
6	Heat-extracted and pressed, pasteurized	6		16
7	Cold-pressed, pasteurized	6		13
8	Cranberry juice cocktail (2)	10	3.4	14
9	Basal Ration only			19

Figure 5. — Vitamin C Content of Whole-Fruit and Strained Cranberry Sauce

	Method of preparing sauce	Grams fed daily	Fresh fruit equivalent *Grams*	Scurvy score
1	Whole-fruit sauce without sugar	14	8	0
2	Whole-fruit "Ten Minute" sauce	10	3.5	5
3	Hot-strained "Ten Minute" sauce	20	7	10
4	Strained sauce, frozen and stored at 0°F	12	9.6	9
5	Commercial whole-fruit sauce (1)	12	4.2	5
6	Commerical strained sauce (1), vacuum packed	20	7	17
7	Commercial strained sauce (2)	20	7	17
8	Fresh, hot-strained sauce	20	7	11
9	Commercial strained sauce (1)	20	7	12
10	Basal Ration only			19

Whole-fruit cranberry sauce prepared in small amounts according to much used recipes (1,23) was found to retain approximately 80 per cent of the vitamin C of the cranberries. In order to make it more palatable to the animals, whole-fruit sauce was prepared without sugar, and the same percentage loss occurred. The time of adding sugar did not alter the results. Commercially packed whole-fruit sauce contained little vitamin C. Samples of two years' packs were assayed, one showing complete destruction and the other a 30 to 40 per cent retention.

Hot-strained cranberry sauce (1) retained a small part of the original vitamin C of the cranberries — possibly 20 per cent. However, five samples of strained sauce prepared by commercial methods retained only traces of vitamin C. Three of these samples were obtained from leading cranberry-sauce manufacturers; the other two were prepared in this laboratory.

One sample of strained sauce was prepared by cooking the cranberries to soften them, cooling, pulping, adding the sugar, and packing in one-pound waxed-paper cartons. The cartons were frozen at –30° F. and stored at 0° F. This sample retained only 10 to 15 per cent of the original vitamin C content of the cranberries.

Summarizing, whole-fruit sauce retains fully three-fourths and strained sauce less than one-fourth of the vitamin C of the fruit. Pulping has a decidedly harmful effect upon the antiscorbutic property of cranberries.

Cranberry Jelly and Candy Filling

Table 5 shows that true cranberry jelly is practically devoid of vitamin C, the experimental animals living but little longer than the controls. The guinea pigs very much disliked this sticky sweet product and they were force-fed only with difficulty.

Cranberry candy filling, consisting mainly of finely chopped cranberries packed in glass jars without heat treatment, showed only very slight antiscorbutic activity. If the fresh berries were chopped and used immediately for candy filler, no doubt a much higher percentage of the vitamin C would be retained.

Vitamin A

The technic developed by Sherman and Burtis (37) and Sherman and Munsell (36) was used in this investigation. Litters of young rats, 28 days old, were placed on a vitamin A-free diet consisting of vitamin-free casein 18, salt mixture 4, irradiated dried brewers' yeast 10, sodium chloride 1, and cornstarch 67 parts. When the body stores of vitamin A were depleted, the rats were placed in individual cages and fed the vitamin A-free diet supplemented by finely ground dehydrated cranberries which were substituted for an equal weight of starch in the diet. One rat from each litter was continued on the vitamin A-free diet as a negative control. Accurate records were kept of the quantity of food consumed and of the weight of the animals. On death or at the termination of the experimental period of 42 days, the rats were autopsied and carefully examined for lesions characteristic of vitamin A deficiency. The data are presented in Table 6.

It is apparent that the quantity of cranberry required to produce unit growth of 3 grams per week is probably slightly over 0.5 gram daily or 8 per cent of dried cranberry in the diet. This would place the vitamin A content of fresh cranberries at about 0.2 unit per gram. These deductions do not allow for possible vitamin A losses during the drying process; hence it is possible that raw cranberries may be richer in vitamin A than is indicated in the dried product. Recent findings (16)

indicate that losses do occur during drying and storage. Fruits comparable to cranberries in vitamin A content are apples, orange juice, and peaches (38).

TABLE 6.— VITAMIN A IN CRANBERRIES

Dried cranberry in diet	Amount of diet consumed daily	Amount of dried cranberry daily	Fresh fruit equivalent	Survival period average	Gain or loss in weight average	Remarks
Per Cent	*Grams*	*Grams*	*Grams*	*Days*	*Grams*	
10	7	0.7	7.0	42	+25.1	Complete protection
5	6.5	.33	3.3	42	+5.8	Very slight xerophthalmia in one rat
2.5	6.5	.16	1.6	40	−.4	Slight xerophthalmia—pus in one rat
1	6	.06	.6	38	−8.8	Xerophthalmia — pus in three rats
0	6	0	0	22	−26	Severe xerophthalmia and copious pus

Vitamin B (B_1)

In the vitamin B investigations the method suggested by Sherman and Spohn (35) and modified by Chase (7) was employed. Healthy young rats, 28 days old, were placed in metal cages with raised wire-screen floors and fed a vitamin B-free diet consisting of vitamin-free casein 18, salt mixture 4, butter fat 8, cod-liver oil 2, autoclaved yeast 15, and starch 53 parts. The animals continued to gain for about two weeks. When growth ceased, their diet was supplemented by dried cranberry powder which was incorporated in the diet in definite proportion, replacing an equal weight of starch. Accurate records were kept of the weights of the animals and the amount of food consumed. The data are presented in Table 7.

TABLE 7. — VITAMIN B (B_1) IN CRANBERRIES

Dried cranberry in diet	Amount of diet consumed daily	Amount of dried cranberry daily	Fresh fruit equivalent	Survival period average	Loss in weight average	Remarks
Per cent	*Grams*	*Grams*	*Grams*	*Days*	*Grams*	
15	8	1.2	12.0	16	−20.5	No better than controls
5	7	.35	3.5	18	−14.7	No better than controls
0	8	0	0	15	−18.9	Definitely neuritic

From these data, it is apparent that the material used contained no vitamin B. Even when cranberry powder comprised 15 per cent of the diet, it did not benefit the animals. Here, of course, even more than with vitamin A, losses might have occurred during the drying. But if a significant amount of vitamin B had been present in the raw cranberries, an amount of the dried material equivalent to 12 grams of fresh cranberries daily should have given at least some protection.

Vitamin G (B_2)

Vitamin G assays were conducted according to the method developed by Bourquin (4). Normal young rats, 28 days old, were placed in metal cages with raised wire-screen floors and fed the vitamin G-free diet consisting of purified casein 18, salt mixture 4, butter fat 8, cod-liver oil 2, and cornstarch 68 parts. The cornstarch carried the alcoholic extract from 50 grams of whole wheat for each 100 grams of diet. The animals were continued on this diet until they ceased growing. At this time the diet was supplemented with dried cranberry which was incorporated

in the diet, replacing an equal weight of starch. Accurate records were kept of the weight of the animals and of the food consumed. The data are presented in Table 8.

TABLE 8. — VITAMIN G (B_2) IN CRANBERRIES

Dried cranberry in diet	Amount of diet consumed daily	Amount of dried cranberry daily	Fresh fruit equivalent	Survival period average	Gain or loss in weight average	Remarks
Per cent	*Grams*	*Grams*	*Grams*	*Days*	*Grams*	
25	8	2.0	20.0	42	+0.3	No better than controls
15	8	1.2	12.0	42	+ .8	No better than controls
0	8	0	0	42	−1.3	Negative controls

These data indicate that cranberries contain very little, if any, vitamin G. Dried cranberry equivalent to 20 grams of fresh cranberry daily caused no significant increase in weight over the controls. Here again some destruction of the vitamin may have occurred during the drying process, but considering the large amount fed, there can be no more than a slight trace present in fresh cranberries.

Vitamin D

The method of testing for vitamin D was that developed by Steenbock and Black (39). Young rats were weaned when they weighed between 45 and 50 grams at about 24 days of age. They were placed on the Steenbock No. 2965 ration consisting of yellow corn 76, wheat gluten 20, calcium carbonate 3, and sodium chloride 1 part. The animals developed rickets in from 28 to 40 days. At this time dried cranberry was added at the rate of 15 and 25 per cent of the diet. This was fed to the animals for a ten-day period, at the end of which X-ray photographs were taken, then the animals chloroformed and line tests carried out. Negative controls were carried to indicate that spontaneous healing had not occurred, and positive controls which received cod-liver oil, in order to allow comparisons.

Animals on both amounts of cranberry showed no improvement over the negative controls. Hence, it was concluded that cranberries contain no significant amounts of vitamin D.

SUMMARY

The American cultivated cranberry, *V. macrocarpon*, is a very good source of vitamin C, the minimum daily protective amount for guinea pigs being 3.5 to 4.5 grams. Varietal differences were slight.

There was a gradual loss of vitamin C in cold storage. However, the loss was only slight during the active marketing season. After four to six months the loss was approximately 20 per cent, and after seven to ten months 60 to 70 per cent. Good keeping quality seemed to be associated with good vitamin C retention.

Inasmuch as vitamin C in cranberries, apples, and possibly other fruits decreases during storage of the fruit, this point must be considered in making vitamin C assays.

Freezing did not injure the antiscorbutic properties of whole, sliced, crushed, or sweetened cranberries. Temperature of freezing and temperature and length of storage had little effect. There was some evidence, however, that thawing and subsequent freezing lowered the vitamin C content.

Evaporated whole cranberries were very deficient in vitamin C. Dehydrated cranberry pulp (film) when prepared in an atmosphere of nitrogen gave full protection from scurvy at the 0.7 gram level, equivalent to a retention of 65 per cent.

Fresh or boiled cold-pressed cranberry juice with or without added sugar was nearly equal to the fruit in vitamin C content. However, when either cold-pressed or heat-extracted juice was bottled and pasteurized, most of the vitamin C was lost. Vacuum sealing of the bottles did not aid in retaining this vitamin.

Whole-fruit sweetened cranberry sauce prepared by several formulas retained 75 to 80 per cent of the fruit's vitamin C. On the other hand strained sauce usually retained less than 20 per cent. The pulping or straining process had a decidedly deleterious effect upon the antiscorbutic vitamin.

When clear cranberry juice was made into jelly, the latter contained no significant amounts of vitamin C. Similarly, cranberry candy filling was very low in vitamin C.

Dehydrated cranberries contained 2 units per gram of vitamin A. Assuming that no loss occurred during dehydration, fresh cranberries would thus contain at least 0.2 unit per gram.

No significant amounts of vitamins B (antineuritic), D (antirachitic), and G (antipellagric) were found in cranberries.

In conclusion it is clear that handling and manufacturing methods may greatly alter the nutritive value of cranberries and cranberry products.

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Publication of this Document Approved by Commission on Administration and Finance.
3500-6-'33. No. 8651

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 297 JUNE, 1933

The Effect of Certain Cropping Systems on the Yield and Quality of Havana Tobacco

By A. B. Beaumont, M. E. Snell and E. B. Holland

A history of one hundred years of tobacco culture in the Connecticut Valley has raised many interesting questions regarding the value of crop rotations and cover crops as compared with continuous culture. This bulletin supplies a record of tobacco yields obtained under a variety of cropping systems.

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Figure 1. — For almost a century tobacco has been the principal cash crop of Connecticut Valley farmers. The crop is at its best on the well-drained alluvial soils as shown here, and under a continuous cropping system.

Figure 2. — Commercial fertilizer supplemented with manure has produced the best quality of tobacco, and the yield has been second best.

Left foreground: Tobacco grown continuously with fertilizer and manure, but no cover crop.

Right background: Timothy (or clover hay) and corn; part of the animal-husbandry rotation. This combination produced tobacco of poor quality and low yield.

THE EFFECT OF CERTAIN CROPPING SYSTEMS ON THE YIELD AND QUALITY OF HAVANA TOBACCO

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Introduction

The earliest New England colonists learned from the American Indians how to grow a number of native American crops including maize and tobacco. Although tobacco was no doubt grown in a small way throughout the colonial period, it did not become a commercial crop in Massachusetts until about one hundred years ago. Smith (17) set the date of commencement of extensive cultivation of tobacco in this State at 1835, when the farmers of the Connecticut Valley found that the soil of this region was well adapted to the production of a very fine leaf for the manufacture of cigars.

All the commercial tobacco produced in Massachusetts is now grown in the Connecticut Valley. Total production in this State rapidly increased from less than 100,000 pounds in 1840 to almost 7,000,000 pounds at the close (1864) of the Civil War (10.) With more or less fluctuation there was a gradual decline in production to about 3,000,000 pounds in 1895-96, a period of rather low prices. Then followed, with a return of better prices, a gradual expansion of acreage and consequent increase in production. The maximum production recorded to date was 15,500,000 pounds grown on 10,000 acres in 1920. From 1920 to 1930 there was a gradual decline in acreage and production, and from 1930 to the present there has been a sharp reduction in acreage, production, and price. In 1929, 11,600,000 pounds of tobacco valued at $4,941,600 were produced on 8,000 acres.

Early Practices in Tobacco Growing

When tobacco culture was introduced into the Connecticut Valley a variety of crops necessary to a self-sufficient agriculture was grown. Chief among these were grass, maize, oats, meslin (peas and oats), rye, wheat, broom corn, hops, barley and buckwheat. It was natural that there should be some rotation of these crops with any newly introduced crop such as tobacco, and this appears to have been the case. In early reports of the Board of Agriculture rotation of tobacco with other crops is implied, and Stockbridge (18) in a paper on crop rotation prepared in 1869 definitely points out that wheat and clover should be grown in the same rotation. A rotation consisting of tobacco (2 yrs.), wheat, clover, and grass, was recommended. The beneficial effect of the tobacco and hay crops on the wheat appears to have been fully as important in the minds of the growers as the benefits accruing to the tobacco.

Again, Smith (17), writing in 1882, mentions the practice of rotation of tobacco and the value of the rotation to the succeeding crops. He also points out the benefit of a certain amount of continuous culture of tobacco. "In the first place, I would prefer land upon which tobacco has grown the two years previous: --- I would not grow tobacco more than three or four years in succession on the same piece, for the reason that I wish to grow this crop in rotation over the whole farm

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[1]Credit is given Dr. J. P. Jones, formerly Research Professor of Agronomy, for careful supervision of the field work reported in this bulletin, for the period 1924-1929, inclusive.

and prepare the land for bountiful crops of grain and grass to follow,---." Apparently, root-rots of tobacco were not known or were of no consequence in the Connecticut Valley in those days (1882).

A generation later, with expansion of acreage, growers were coming to feel that they could not afford to rotate tobacco with other crops because of the much lower return. However, some rotation of tobacco was practised. Root-rot diseases were becoming common. Jenkins (11) in discussing the fertility problem in 1906 stated that some cropping system should be practiced which would permit more organic matter to be incorporated in the soil. "I believe a certain amount of rotation would be of great advantage to us if we could afford it. At any rate, I think, either by cover crops or catch crops, or manure we should get more vegetable matter into our tobacco soils." However, "down in Connecticut they say tobacco improves the longer you grow it; a lot 40 years old raises better tobacco than at first." Jenkins also stated, "it is a tradition that you get poor tobacco after corn," but cases were known where excellent tobacco was grown after this crop.

Records show that manure was the principal fertilizing material used in the growing of tobacco in this section for the first 50 years of its commercial culture. This was supplemented more or less with such commercial fertilizers as were obtainable. For example, Lathrop and Stockbridge (15) in 1862 recommended "at least 10 cords (25-30 tons) of good manure with 200 pounds of plaster sown on after it (manure) is spread." Smith (17) in 1882 recommended the use of 25 cartloads of manure broadcast supplemented by 12 to 15 cartloads of manure compost strewn in the furrow just prior to setting tobacco. He also cites the record of a farmer who used 5 cords (12.5-15 tons) of manure supplemented with 1 ton of commercial fertilizer, and another who used no manure at all but 1.5 tons of tobacco stems and 800 pounds of ground bone. During the past 50 years, with a less varied agriculture and consequent diminishing supply of stable manure, this material has been used less and commercial fertilizers more. Many Connecticut Valley farmers now depend entirely on commercial fertilizers for tobacco culture and use 3000 to 4000 pounds per acre.

The use of cover crops in tobacco culture appears to have been started at about the turn of the century. Largely on the basis of theory it was argued that by some means organic matter should be supplied to take the place of the diminishing manure supply. Since tobacco was most commonly grown in continuous culture, cover crops offered the best means of doing this. In addition to any possible soil fertility value they were known to serve a useful purpose in checking wind and water erosion of the soil and in conserving plant nutrients against loss by leaching. The small grains, particularly rye and vetch were first used, followed later by a quite extensive use of timothy.

Is the Yield of Tobacco Decreasing?

For the past decade or two tobacco farmers of Massachusetts have rather generally believed that the level of production of tobacco per acre has been declining. This question was treated with considerable detail by Chapman (7) in 1920. His conclusion was that there was at that time "no justification for the statement that the yield of tobacco of Massachusetts fields has been decreasing gradually for the past ten years; but on the contrary, in spite of the exceedingly low yield of 1915 the calculated average is being maintained." The calculated average was that for the period 1870-1910, namely 1580 pounds.

In view of the generally prevailing notion of declining yields, it is worth while to consider the bearing on this question of yield data accumulated within the past

decade. In Table 1 are given yield averages for the seven decades between 1860 and 1930, calculated from figures given by Hendrickson (10). In attempting to analyze these data, it should be remembered that the figures are only close estimates subject to the limitations of all such figures collected by the crop reporting service. However, they are the only official figures available for the area considered and probably accurate enough for the purpose in mind.

TABLE 1 — AVERAGE YIELD OF TOBACCO IN MASSACHUSETTS BY 10-YEAR PERIODS*

Period	Average Yield
1862 - 1869, except 1866	1256
1870 - 1879, except 1877	1505
1880 - 1889, except 1889	1486
1890 - 1899, except 1890, '91, '92, '94, '97, '98, and '99	1623
1900 - 1909	1679
1910 - 1919	1558
1920 - 1929	1335

*Hendrickson, C. I. A history of tobacco production in New England. Conn. (Storrs) Agr. Expt. Sta. Bul. 174. 1931.

It will be seen from the table that there was a rather gradual increase in yield up to the first decade of the present century, since which time there has been a decline[2]. The data support the general opinion among farmers that yields have been declining. This decline is especially obvious when recent decades are considered in comparison with the peak of production of the period 1900-1909, rather than with the mean of the period 1870-1910. The former would seem to be a better basis for comparison than the latter because there was considerable variation in cultural practices during the period 1870 - 1910. It was within the latter part of that period that continuous culture of tobacco and a more intensive use of fertilizers became common, both practices tending to increase yields.

Chapman (7) concluded from his study of meteorological data for the period 1901-1917 that "excessive seasonal rainfall is invariably followed by a reduction in yield independent of temperature," but that subnormal rainfall may or may not reduce yields, depending on accompanying temperatures and how far below normal the rainfall is. Data accumulated since 1917 appear in general to support these contentions, but there are some exceptions. The close relationship between heavy rainfall and low yields appears pretty well established by the data of the past few years. This is especially interesting and probably significant in view of the belief that the root-rots of tobacco have become more prevalent in this section in recent years and that the root-rots are largely the cause of declining yields. This phase of the subject will be discussed later.

Cropping Systems Studied

The principal objective of the experiment was to determine the effect of certain cropping systems on the yield and quality of tobacco. The crops selected were among those grown more or less in the Connecticut Valley, and the combinations were either used by farmers or advocated by certain agricultural leaders.

The cropping systems studied may be classified into three general groups:

[2]Havana seed tobacco was introduced into the Connecticut Valley about 1870, and this type gradually and almost entirely displaced Broadleaf in Massachusetts. Shade tobacco began to assume importance in Massachusetts in 1915 when 586 acres were grown. While the shift of growers from one type to another, or the temporary increase of acreage of a given type, may have influenced the average yields, the trends indicated in Table 1 appear to have been due largely to other factors.

first, tobacco grown continuously without a cover crop; second, tobacco grown continuously with a cover crop; and third, tobacco grown in a short rotation. The combinations used in the main experiment were:

Tobacco grown continuously:

1. No cover (check)
2. Manure
3. Manure and timothy cover
4. Timothy cover (old series)
5. Timothy cover (new series)[3]
6. Timothy cover (residual)[3]
7. Red top cover
8. Rye cover

Tobacco grown in rotation:

9. With corn (maize) and timothy (Animal husbandry rotation)
10. With corn (maize) and clover (Animal husbandry rotation)
11. With potatoes and onions (Cash crop rotation)

In addition there were certain other combinations in a supplementary experiment running from 1924-1929 which will be described later. Cover crops were sown on a seed-bed prepared by disking the soil immediately after cutting tobacco, at the following rates: Timothy, 25 pounds per acre; red top, 20 pounds per acre; and rye, 1.5 bushels per acre.

The Soil Used

The soil on which the experiment was conducted is considered good for tobacco growing, but not the best of the upper Connecticut Valley. It is a water-worked glacial till, and not so productive as some of the deeper alluvial deposits of this section. The surface soil has a medium texture, is classified as a fine sandy loam or loam, and is fairly retentive of moisture. At a depth which varies from almost nothing to about fifteen inches it is underlaid by coarse gravel three feet or more deep. The fine-earth (below 2mm) portion of the soil contained 11.2 per cent fine sand (0.25-0.10 mm), 33.8 per cent very fine sand (0.10 - 0.05 mm), 42.5 per cent silt (0.05 - 0.005 mm), and 8.5 per cent clay (0.005 mm and smaller). The initial reaction of the soil was about pH 5.2 and the organic-matter content at the beginning of the experiment was 2.72 per cent. The effect of the cropping systems on these soil characteristics will be discussed later.

This experiment began with the crop of 1924, although tobacco was grown on the field in 1923. For about fifteen years previously a variety of crops, including asparagus, onions, potatoes, squash, corn, and strawberries, was grown. All these crops were well fertilized.

The Fertilizer Used

The experiment did not involve any question concerning fertilizers except that of supplying a uniform material in general conformity with the best practice of the growers of the region. Throughout the period of the experiment a 5-4-5 mixture was used. Due to differences between guaranteed and actual analysis of the fertilizer ingredients used, there was some variation from the standard from year

[3] In 1928 the growth of timothy as a cover crop was discontinued on five plots where it had been grown from 1924-1927; and from 1928-1931 the residual effect of the timothy was studied on these plots. At the same time the use of timothy as a cover crop was started on five plots where it had not been grown previously.

to year. Also, there was a variation in the ingredients used in the mixture during the period of the experiment. For example, in the first year cottonseed meal furnished 70 per cent of the total nitrogen, and in subsequent years about 50 per cent. There were variations also in the kind and proportions of the carriers of inorganic nitrogen and in the quantity of fertilizer, 3000 pounds per acre having been used during the period 1924 - 1927 and 3500 pounds during 1928 - 1931. These variations could cause differences only in the whole experiment from year to year or period to period, but could not be considered as causes of differences within the experiment for any one year, since a uniform fertilizer treatment was given all plots with a few exceptions noted later. Detailed data of fertilizer mixtures are given in Table 2. Figures for nitrogen and phosphoric acid express the total quantities of these elements.

TABLE 2 — TOTAL NUTRIENTS APPLIED IN THE DIFFERENT CROPPING SYSTEMS.

(Pounds per Acre)

	Nitrogen (N)			Phosphoric Acid (P_2O_5)			Potash (K_2O)		
Year	1	2	3	1	2	3	1	2	3
1924	123.2	198.9	198.9	163.6	241.0	241.0	150.6	255.5	255.5
1925	123.4	207.1	207.1	151.6	229.0	229.0	149.3	261.4	261.4
1926	125.1	217.0	217.0	155.7	245.1	245.1	150.2	276.8	276.8
1927	119.1	181.5	173.4	147.2	205.2	188.4	149.5	235.7	228.0
1928	142.0	231.0	186.2	180.5	253.8	201.3	175.2	275.3	221.3
1929	146.2	204.8	179.6	168.4	225.4	194.3	180.8	299.7	277.6
1930	149.1	242.3	195.8	171.0	253.1	202.2	184.4	286.5	230.3
1931	145.9	210.4	165.5	167.2	245.5	193.4	190.0	275.2	216.5
Averages:									
1928-1931	145.8	222.1	181.8	171.8	244.5	197.8	182.6	284.2	236.4
1926-1931	137.9	214.5	186.2	165.0	238.0	204.1	171.7	274.9	241.7
1924-1931	134.3	211.6	190.4	163.2	237.3	211.8	166.2	270.7	245.9
1924-1927	122.7	201.1	199.1	154.6	230.1	225.9	149.9	257.3	255.4

1 = Continuous tobacco, with and without (check) cover crops; and cash crop rotation.
2 = Animal-husbandry rotation.
3 = Continuous tobacco with manure.

The Plan of the Principal Experiment

This experiment was laid out on the chessboard plan which permits the distribution of the replicated treatments in such a manner that a comparison can be made between the results of any pair or among the entire set of treatments. In using such a plan, considerable replication of plots of a given treatment is necessary. As will be shown later, the experimental error of field experiments of this nature is high at best, and every feasible device must be used to reduce the error to a minimum.

The dimensions of the original plots were 60.5 by 36 feet, or 1/20 acre, exclusive of a border of 6 feet around each plot. The border was fertilized, planted, and cultivated in the same manner as the plot proper, but its yield was not taken. In the original plan of the experiment, possible later subdivision of the plots to meet needs which might develop in the course of the experiment was contemplated, and in 1926, after the first two years, several of the plots were subdivided into halves. Still others were subdivided in 1928.

The tobacco-setting machine was set to space the plants 21 inches apart in the row. The average number of plants per 1/40 acre plot at the end of the season for eight years was 198.3, against a theoretical 207.4 for perfect spacing and perfect stand. Rows of tobacco were 3 feet apart. With the exception of the two rotation series, all of the treatments were replicated at least four times and most of them five or more.

Discussion of the Results of the Experiments

The correct interpretation of the results of field experiments such as are reported in this bulletin is extremely difficult. Unavoidable variations in soil and climate are the most stubborn factors the agronomist must deal with in the interpretation of his results. Every feasible device must be used to obtain a reasonable degree of assurance that the differences in results are due to the treatments considered instead of to chance variation in soil, climate, or some other variable. The effects of soil variation can be reduced but not eliminated by the replication of plots given a certain treatment; likewise, chance variation due to climate can be reduced by repeating the experiment a sufficient number of years to give a fair sample of the climate. This experiment is concerned with the effect of different cropping systems on yield and quality of tobacco.

1. *Effect of Cropping Systems on Yield*

In Tables 8-18 are given the yields and grades of tobacco grown under the different cropping systems. For convenient comparison the results are summarized in Table 3 and averaged for the different periods. Fair comparisons can be made only among results of treatments which covered the same period. Thus, the treatments "continuous tobacco: no cover (check)," "manure," and "timothy cover" ran the entire course of the experiment.

It will be seen from the table that for each of the periods the manure treatment yielded more tobacco than either of the others. Further, timothy cover yielded slightly less than no cover or check for the periods 1924-1927 and 1924-1931, but slightly more for 1926-1931, and considerably more for 1928-1931. This indicates a recovery in the latter part of the experimental period from the inhibiting effect of timothy shown in the first part of the period and reported by Jones (13). The figures for all treatments show that red top cover produced the most pounds of tobacco for the period 1926-1931 and likewise for the period 1928-1931. Rye was slightly superior to timothy as a cover for 1926-1931, but the relation was reversed for 1928-1931.

It will be observed that there is little difference between some of the average yields cited. The question naturally arises as to what significance attaches to the differences. How much higher must one average yield be than another to be significant? A statistical study[4] has been made of the results, which throws some light on the question. By replicating plots of the same treatment several times, and by conducting the experiment for several years, the probable error of a single plot has been reduced to less than 5 per cent, and the probable error of the mean (average) to less than 1.5 per cent, both expressed as percentages of the mean. This means that there must be a difference of about 6 per cent or about 95 pounds before one average can be considered as significantly greater or less than the other. In other words, differences in averages much less than 95 pounds, for the period 1926-1931, may be due to chance variation instead of to the treatment in question. By this criterion the average yields from red top cover and manure are the only ones sufficiently near the requirement to make it reasonably certain that the difference is due to the treatment instead of to chance. For the same period, yields from no cover, timothy cover, and rye cover are so close that no particular significance can be attached to the differences.

The yields of tobacco from the two rotations are so much below those of the check that there is little question about the significance of the differences, although

[4]See appendix for note on method of statistical interpretation.

since there were only duplicate treatments the results cannot be treated statistically. It will be noted that yields from the two animal-husbandry rotations were particularly low, with clover the lower. These results will be discussed later in connection with brown root-rot. The results from those treatments which ran for the period 1928-1931 only, can be considered mainly only in the light of showing trends. These trends correspond rather closely with the results from similar treatments for the longer period.

TABLE 3 — AVERAGE GRADE INDEX, YIELD, AND CROP INDEX OF TOBACCO GROWN UNDER DIFFERENT CROPPING SYSTEMS.

Cropping system	1924-1927	1928-1931	1924-1931	1926-1931
Grade Index				
Continuous Tobacco:				
No cover (check)	.319	.399	.359	.390
Manure	.346	.419	.383	.413
Manure and timothy cover	....	.413	....	....
Timothy cover (old series)	.307	.398	.352	.390
Timothy cover(new series)	....	.394	....	....
Timothy cover (residual)	....	.394	....	....
Red top cover	.367*	.408	....	.394
Rye cover	.372*	.403	....	.393
Rotation Tobacco:				
With corn and timothy	.205†	.306‡	.255§	....
With corn and clover	....	.315‡	....	....
With potatoes and onions	.284	.348**	.316††	....
Yield (Pounds per Acre)				
Continuous Tobacco:				
No cover (check)	1442	1610	1526	1603
Manure	1492	1711	1602	1693
Manure and timothy cover	....	1674	....	....
Timothy cover (old series)	1301	1686	1494	1620
Timothy cover (new series)	....	1651	....	....
Timothy cover (residual)	....	1608	....	....
Red top cover	1604*	1743	....	1697
Rye cover	1577*	1647	....	1624
Rotation Tobacco:				
With corn and timothy	998†	1300‡	1149§	....
With corn and clover	....	1257‡	....	....
With potatoes and onions	1330	1414**	1372††	....
Crop Index				
Continuous Tobacco:				
No cover (check)	467.7	650.3	559.0	630.3
Manure	524.3	727.0	625.6	705.0
Manure and timothy cover	.....	696.1	.....	.....
Timothy cover (old series)	410.9	676.8	543.8	637.2
Timothy cover (new series)	.....	658.0	.....	.....
Timothy cover (residual)	.....	644.4	.....	.....
Red top cover	588.6*	716.7	.....	674.0
Rye cover	586.6*	669.5	.....	641.9
Rotation Tobacco:				
With corn and timothy	202.8†	402.9‡	302.9§	.....
With corn and clover	.....	400.4‡	.....	.....
With potatoes and onions	383.8	193.0**	138.4††	.....

* For 1926 and 1927.
† 1926 omitted.
‡ 1929 omitted.
§ 1926 and 1929 omitted.
**For 1928 and 1929.
††For 1921 - 1929.

2. *Effect of Cropping Systems on Quality*

Two measures of quality have been employed in this project — commercial grading and the burn test. The percentage of the different grades of tobacco grown under the several cropping systems are given in Tables 8-18. The percentages have been combined by a method described in the appendix into a numerical expression known as the "grade index." Thus, the superior grading quality of tobacco sorting out high percentages of "lights," "mediums" or "seconds" is shown by this index. Compare, for example, the percentages of the different grades in the crops grown with manure and in rotation, Tables 9 and 16 or 17, with the grade indexes for those crops. The product of the grade index by the crop yield gives a single numerical expression known as the "crop index" which combines yield and grading quality. Grade and crop indexes are summarized in Table 3.

Commercial tobacco grading as practiced in the Connecticut Valley cannot be reduced to an exact science. No two graders will grade a given lot of tobacco in the same way. Since there were three different grading supervisors in the course of the experiment, some of the differences in percentage of grades may be attributed to the different personalities. Perhaps a more important factor affecting the variation in quality from the same treatment is that of climate. For example, in 1930, a year of low rainfall, both grade and yield were exceptionally high; whereas in 1929, a year of exceptional drought, and in 1928, a wet season, the quality was poor. The grade index was generally better for the period 1928-1931 than for 1924-1927, which may be attributed in part to the larger application of fertilizer in the period 1928-1931.

Continuous tobacco with fertilizer and manure produced the best quality of tobacco, as shown by a higher grade index for this treatment for every period in which a direct comparison with other treatments may be made. Red top cover gave a grade index slightly better than the other cover crops, but the difference is so slight that it is probably no more than a chance variation. The quality of the tobacco from the three rotations was decidedly poor. The effect of the different treatments on the percentage distribution of the different grades is shown in Tables 8-18, and on the length of leaf within the different grades in Table 24 of the appendix. Since the manure treatment gave the best grading quality of tobacco, one may set up as a standard at which to aim, the average percentage distribution of the grades of this crop as shown in Table 9.

Since the crop index combines grading quality and yield into a single number, particular attention should be given the crop indexes given in Table 3. Here it will be seen that continuous tobacco with fertilizer and manure gave the best net result. This means that the farmer would get a better financial return from tobacco grown with this treatment than with any other studied, if due consideration were given to quality by the buyer. Although the yield was slightly better with red top cover than with manure without a cover, the superior quality of the tobacco grown with the manure raised its crop index above that from red top. The differences of both these treatments from the check are sufficiently great to be significant, but the indexes for rye and timothy cover are not significantly higher than the check. The crop indexes of tobacco from the rotations are definitely low, and the others are in line with previous statements.

3. *Effect of Cropping Systems on Brown Root-Rot of Tobacco*

Root-rots have been known to exist on tobacco grown in the Connecticut Valley since the latter part of the last century. It has been observed that they were associated with, if not the cause of, low yields in individual cases, and some have

suggested that the root-rots have been the main cause of the diminished level of yields of the past decade or two. The cause and remedy of black root-rot of tobacco are now pretty well understood. However, little is known about the cause and remedy of the so-called brown root-rot.

There are two schools of opinion regarding this disease or condition. The one claims that it is caused by a specific parasite which attacks the root; the other is of the opinion that a soil condition is the cause. The soil condition may be that of a deficiency of a given nutrient or special form of it, or the presence of a plant toxin.

One of the great difficulties encountered in the study of the nature and cause of brown root-rot is the lack of definition of the disorder and the inability to detect its presence with certainty. It appears likely that there may be several possible causes of brown roots of tobacco. For example, Jones (14) has shown that soluble aluminum, and Beaumont (5) that ammonium compounds, may cause the roots of tobacco to turn brown or dark in solutions. Doran (8) has shown that timothy infusions in certain stages of decomposition may cause a brown root-rot. Moreover, it appears that normal, healthy tobacco roots may become slightly brown without deleterious effects on growth. A systematic examination of the roots of tobacco grown in this experiment showed that what would ordinarily be diagnosed as brown root-rot was nearly always present to some extent in the tobacco regardless of treatment. Tobacco grown in the animal-husbandry rotation showed the highest percentage of infection, but it was relatively low for tobacco grown continuously with no cover. In the rotation including clover there was a higher percentage of brown roots than in that with timothy. Brown roots were found on 48 per cent of the plants grown with red top and rye covers and on 60 per cent of those with timothy cover. These figures should be considered as estimates only, because of the difficulty of diagnosing the conditions. The results of root examinations are summarized in Table 4.

TABLE 4 — PERCENTAGE OF TOBACCO ROOTS SHOWING PRESENCE OF ROOT-ROTS*

(Average for 1925-1931)

	Black root-rot	Brown root-rot
Continuous Tobacco:		
No cover (check)	17	27
Manure	19	29
Timothy cover (old series)	5	60
Red top cover	6	48
Rye cover	11	52
Rotation Tobacco:		
With corn and timothy	0	84
With corn and clover	0	100
With potatoes and onions	9	55

*All roots showing any appreciable amount of root-rot were counted. The above figures indicate the average percentage of infected roots, but not degree of infection.

In severe cases of brown root-rot, portions of the tobacco plant above the ground show characteristic symptoms. From two to three weeks after growth starts the plants begin to lag behind unaffected plants in growth. The leaves develop a darker green color than is shown by normal plants. The lower leaves develop slowly compared to the new growth, and the plant appears spindling or slender.

Towards the end of the growing season, there is usually more or less recovery from these conditions. The final results of the malady are reflected in the low yields and poor quality of the crop. In these experiments brown root-rot has been slightly more severe following clover than following timothy in rotation.

4. *The Effect of Tobacco and Other Crops on Each Other*

The effect of certain other crops on the yield and quality of tobacco when grown in rotation with it has been discussed. Any rotation suitable for tobacco should give at least fair returns of the other crops. In Table 20 are given the yields of all the crops grown in the cash-crop rotations. The yield of potatoes was rather variable from year to year. This can be explained partly by seasonal variations and partly by the fact that there were only duplicate plots of each treatment, which was too few to take care of differences in soil. Nevertheless, with an average yield of 268 bushels of marketable potatoes, the evidence is strongly in favor of the conclusion that potatoes may be expected to do well in rotation with tobacco in the Connecticut Valley. For both crops the reaction of the soil should not be above pH 5.5, because above that point potatoes may become infected with common scab (*Actinomyces scabies* Thax.), and tobacco with black root-rot (*Thielavia basicola* (B. & Br.) Zopf.).

Additional evidence bearing on the question of the effect of potatoes and tobacco on each other when grown in the same rotation was obtained from a supplementary field experiment in which tobacco was grown alternately with other crops. For checks, each of the crops was grown continuously on an adjacent plot. In one series of plots, tobacco, onions, and potatoes were thus grown; and in the other, tobacco, corn, and hay were grown. This experiment differed from the rotations previously described in that the crops were grown either continuously or in alternating pairs. There was no rotation of the three crops. The experiment ran six years, but the first year's results are not taken into account because one year was needed to establish the desired conditions. Since there was only a single plot for each treatment, except for tobacco which was duplicated, the results may be considered mainly as showing trends. (See Table 23.)

Here again, the results indicate that potatoes and tobacco do about as well as any of the combinations studied. Continuous tobacco appears to have a slight advantage over the tobacco-potato combination, but potatoes did slightly better following tobacco than in continuous culture.

Onions did poorly in rotation with potatoes and tobacco, probably because of the strong acidity of the soil in this rotation. Infestations of thrips and the presence of "blight" in some years reduced the yields to a low point. The yield of onions was better under continuous and alternate cropping systems than in the 3-year rotation as shown by figures in Tables 20 - 23. This was probably due to the fact that more lime was applied under the former system than in the latter. It will be seen, also, that continuous culture of onions was better than alternate cropping, which may be attributed to the use of more lime. Other experiments conducted at this experiment station showed that onions have a high lime requirement. For best results, onion soil should have a pH value of 6.0 - 6.5.

In the so-called animal-husbandry rotation manure was applied to the tobacco in such amount as would theoretically be produced from crops grown in the other two years had they been fed to livestock, and this in addition to a normal application of fertilizer. As shown by Table 2 this method caused the total amount of applied nutrients to be rather high. In addition a timothy or clover sod was plowed under. Nevertheless, as has been shown, the tobacco was low in yield and

poor in quality. The corn and hay crops received, with few exceptions, the standard fertilizer for such crops. The high yield of corn in 1925 was probably due to a double application given that year; likewise for timothy hay in 1931. Generally the corn did well and the timothy hay poorly in the rotation. In contrast, clover hay did much better in the same rotation (Table 22). It is believed that the strong acidity of the soil in this rotation affected the timothy more adversely than it did the clover. In the supplementary experiment corn did somewhat better after tobacco and hay than in continuous culture. Hay was much better after tobacco than after corn.

5. *The Influence of Cropping System on Burn*

Burn tests were made on unrolled leaves of the long dark (LD) and long second (LS) grades of tobacco from the different treatments. These two grades together constitute more than 50 per cent of the better-quality tobacco. Each leaf tested was ignited with an electric hot point at two places on each side of the midrib, and the duration of the burn determined in seconds with a stop-watch. Five leaves were selected from each plot after the tobacco had gone through the sweating (fermentation) process. Therefore, in case of five replicated plot treatments 100 tests were obtained for each treatment. The average results are given in Table 5. In the tests of 1930 no burn was timed beyond 60 seconds. Prior to that time, the duration of the burn was recorded without limit.

TABLE 5 — BURN TESTS ON SWEATED TOBACCO LEAVES.

(Duration of Burn in Seconds)

Cropping System	1926	1927	1928	1929	1930	Average
Darks						
Continuous Tobacco:						
No cover (check)	8.2	9.4	32.5	11.0	4.3	13.1
Manure	4.5	9.7	46.7	8.8	3.1	14.6
Manure and timothy cover	....	....	20.3	6.5	3.7	10.2*
Timothy cover (old series)	6.8	9.3	36.5	12.0	3.4	13.6
Timothy cover (new series)	....	....	34.8	7.9	5.5	16.1*
Timothy cover (residual)	....	....	25.7	8.6	4.6	13.0*
Red top cover	9.3	12.0	27.2	5.0	4.5	11.6
Rye cover	5.3	8.8	26.9	13.7	5.4	12.0
Rotation Tobacco:						
With corn and timothy	....	4.7	12.7	3.5	3.3	6.0*
With corn and clover	....	....	18.2	4.9	4.7	9.3*
With potatoes and onions	6.1	5.0	23.2	6.0	2.9	8.6
Seconds						
Continuous Tobacco:						
No cover (check)	13.1	26.1	60.6	20.6	24.6	29.0
Manure	11.7	25.6	63.0	24.5	30.4	31.0
Manure and timothy cover	....	....	96.0	14.5	23.7	44.7*
Timothy cover (old series)	9.2	12.9	48.7	17.7	29.4	23.6
Timothy cover (new series)	....	....	48.1	19.2	20.8	29.4*
Timothy cover (residual)	....	....	48.3	17.5	19.2	28.3*
Red top cover	15.5	22.5	48.5	18.1	25.9	26.1
Rye cover	9.2	19.2	47.4	13.2	28.1	23.4
Rotation Tobacco:						
With corn and timothy	....	23.7	31.3	6.4	11.9	18.3*
With corn and clover	....	....	30.5	5.1	6.6	14.1*
With potatoes and onions	6.5	7.8	45.0	5.5	18.1	16.6

*These averages not strictly comparable with those for the longer periods.

The results indicate a fair degree of correlation between the burning quality and grading quality of the tobacco as influenced by cropping system. Manure has given the longest average burn, closely followed by no cover and the several cover crops. Tobacco from the rotations had a definitely short duration of burn. As will be brought out later in the discussion of the effect of cropping systems on soil conditions, nitrates accumulated in the greatest amount where manure was used, and this may account in part for the long burn shown by tobacco from this treatment.

From the standpoint of seasons it is interesting to observe that the longest burn for all treatments was obtained in 1928, a year of heavy rainfall, low yield, and poor grading quality. A possible explanation of this relationship lies in the correlation which Anderson and others (2) have pointed out between wet seasons and the potash content of tobacco leaf on the one hand, and potash and fire-holding capacity on the other.

6. *Effect of the Cropping Systems on Soil Conditions*

In Table 6 is shown the effect of the cropping systems on the reaction of the soil. The reaction was determined on air-dried samples taken at the beginning of the experiment and in 1932. The results are as would be expected from theory. In general, the continued cropping of soil without the addition of lime or organic matter may be expected to make it more acid because basic materials are removed faster than acidic, both by the crop and through leaching. Continuous culture of tobacco without a cover crop caused the reaction to drop (become more acid) 0.5 pH unit. With cover crops and manure, probably because of the ash residue of the organic matter, the change was 0.2 to 0.4 of a unit. Likewise, the rotation with corn and timothy lowered the reaction only 0.3 unit. In the cash-crop rotation a total application of 2 tons of limestone offset a decrease due from cropping, and in addition raised the reaction 0.2 unit.

TABLE 6 — EFFECT OF CROPPING SYSTEMS ON SOIL REACTION*

	(Reaction pH) Initial	Final
Continuous Tobacco:		
No cover (check	5.3	4.8
Manure	5.0	4.7
Manure and timothy cover	5.3	5.0
Red top cover	5.2	4.8
Rye cover	4.9	4.7
Rotation Tobacco:		
With corn and timothy	5.3	5.0
With potatoes and onions†	5.2	5.4

*Determined on air-dry soils with potentiometer using quinhydrone and saturated calomel half-cell. 1 part of soil mixed with approximately 2 parts water.

†This rotation was used 1923-1929; changed to tobacco, corn, and timothy in 1930.

Since many of the students of the problem of decreasing productivity of certain Connecticut Valley tobacco soils suggested as a remedy practices which would add more organic matter to the soil, it was decided to determine the effect of the different cropping systems studied on the content of soil organic matter. Organic carbon was determined by a wet-combustion method, and organic matter was calculated. Analysis was made of composite soil samples representing the several treatments drawn at the beginning of the experiment and at the close of the cropping season of 1932. The results are given in Table 7. It will be seen that the

different cropping systems produced little or no effect on the content of soil organic matter. Certain differences between the initial and final organic matter content of soils under different treatments will be noted, but lack of consistency in most of them suggests that the differences shown may be due to little, if any, more than chance. The organic matter has not been materially affected where no means of maintaining it have been employed, as shown by the no-cover or check plots. Likewise, the use of a rye cover has maintained the organic matter. There is consistent indication of an upward trend of organic matter content wherever timothy has been used either as a cover or as one crop of a rotation. A slight increase is to be noted for clover in rotation. On the other hand, a downward trend is indicated with red top cover and manure.

TABLE 7 -- EFFECT OF CROPPING SYSTEMS ON ORGANIC MATTER* IN TOBACCO SOILS.

(Average percentage of organic matter based on oven-dry weight of soils)

Treatment		Organic Matter 1923	Organic Matter 1932
No cover		2.45	2.36
Manure		3.02	2.81
Manure and timothy cover		2.66	2.96
Timothy cover		2.64	2.96
Rye cover		2.45	2.49
Red top cover		2.87	2.75
Rotation with timothy	old	2.38	3.14
	new	2.65	3.45
Rotation with clover	old	2.83	2.90
	new	3.03	3.10

*Calculated from organic carbon using factor 1.724.

In discussing the question of the value of organic matter in a cropping system, consideration should be given to the type of organic matter determined and changes which it may have undergone in the soil. As usually determined, and as was done in this experiment, soil organic matter consists of the more stable and less active forms of carbon compounds. Succulent cover crops, crop residues, and animal manure decompose comparatively rapidly in soils having optimum moisture, good aeration and a temperature such as prevails during the summer months in this region. Cultivation of the soil serves to hasten the process. It may be expected that moderate quantities of organic matter added to the soil in the form of cover crops, crop residues, or fertilizer will largely disappear in the course of one season; and this is what the data appear to have proved. What has been determined is the relatively inert, stable organic matter remaining in the soil, and not the intermediate decomposition products which may or may not have been beneficial.

It does not necessarily follow, therefore, that since a given addition of organic matter has not materially changed the quantity of stable organic matter that it has not been beneficial or detrimental. It appears that both effects have been demonstrated in the cropping systems studied. Red top cover has produced both a high yield and good quality of tobacco. Timothy cover has only slightly improved yield and has had no effect on quality. Tobacco grown in rotation with timothy has been poor in both yield and quality, but here there is a complication

due to the presence of corn in the rotation. How can the difference in the effects of red top and timothy be explained? The answer possibly lies either in the rate of decomposition or the nature of the decomposition products of the two grasses. The data obtained indicate but do not prove that red top decomposes more rapidly than does timothy. Possibly certain toxic products result from timothy which do not arise from red top, or they exist longer in the soil. Or considered from the positive side, certain beneficial products may be produced from red top which do not come from timothy, or they may be produced in greater quantity, or persist for a longer time. A similar line of reasoning may be applied to a comparison between some of the other cropping systems and the use of manure.

It has been shown by earlier investigations at this experiment station reported elsewhere (4) that the nitrate form of nitrogen was the most easily assimilated of a number studied. Studies of the formation of nitrates in the field soils of this experiment have shown some degree of correlation between the rate of accumulation of soil nitrates and the yield and quality of tobacco. This relationship has been particularly marked in the case of the quality of tobacco grown continuously with a manure supplement. Under this treatment the accumulation of soil nitrates has been highest, especially near the end of the growing season, and the tobacco has been of outstandingly superior quality as shown by both grade index and burn test. In addition to the possible agronomic benefits from cover crops there are some unmeasured and unmeasurable benefits not hitherto mentioned. At certain times of the year, particularly within the winter and spring, strong winds sweep down and across the Valley, sometimes for days at a time. Considerable soil is removed (3) from bare fields and is transported in dense clouds (see Figure 3). This is not only an economic loss to tobacco growers but constitutes a public nuisance for the farmers and villagers of the Valley. In addition to allaying this wind erosion of soils, cover crops in tobacco fields are also used by some farmers for temporary fall pasture, and this may be an important advantage.

Massachusetts Compared with Other States

Since comparisons are frequently drawn between practices in growing tobacco in the Connecticut Valley and elsewhere, a discussion of results obtained here in comparison with those reported from other experiment stations will be worth while. In such a discussion it should be recognized that differences in climate, soil types and conditions, types of tobacco grown, fertilizer and cultural practices and other indefinable factors limit the value of strict comparisons.

In the early years of the industry in the Connecticut Valley rotation of tobacco with other crops was the rule; but in recent years, for reasons which have been stated, tobacco has been grown mainly in continuous culture on the land best adapted to it, and an intensive culture involving large amounts of commercial fertilizer has developed. Until the past decade this system has enabled the Connecticut Valley to lead all other sections of the United States in the yield per acre, but recently yields have not been maintained, and Pennsylvania has taken the lead.

Until rather recently it was common practice in the shade-tobacco district of Florida (19) to follow a system of continuous culture. This was largely a matter of economy. Recently, due to the increase of certain soil-harbored diseases, tobacco growers in that section have been forced to rotate crops or let the land remain idle for a period. In all other sections of the South tobacco has from the beginning of the industry been grown on "new" or recently cleared land, or in some sort of a rotation, or the land has been "rested" or allowed to remain idle.

Although there is no experimental evidence that these methods are better than that of continuous culture, they appear to be satisfactory for the conditions prevailing in those sections. In comparison with the conditions and practices of the Connecticut Valley, it should be pointed out that comparatively small amounts of commercial fertilizer and manure are used. Also, yields per acre of tobacco are much below that of the Connecticut Valley.

In experiments with cropping systems conducted in Maryland (6), rotations were shown to produce more tobacco than did continuous culture, but the results were lacking in consistency. Inconsistent results were obtained from the use of cover crops; rye, and crimson clover having depressed the yield, while vetch increased it. The authors concluded from the experiments: "Except in the case of red clover in a three-year rotation with tobacco and wheat, the results indicate that the legumes in these tests cannot be relied upon to give uniformly satisfactory results with tobacco if grown more than two or three times in continuous culture of tobacco or in short rotation of tobacco with other crops."

In Wisconsin, an important tobacco section, it is rather common practice to rotate tobacco with other crops, but Johnson and Ogden (12) have shown that rotations involving sod-forming crops may be very harmful to tobacco. They ascribe the disease of tobacco known as brown root-rot to the effect of preceding crops, and estimate that over 50 per cent of the tobacco crops of Wisconsin are affected more or less adversely by preceding crops. Timothy and alfalfa in particular are known to produce harmful effects on tobacco. Continuous culture of tobacco is a remedial practice. Conditions surrounding the production of tobacco in Wisconsin more nearly parallel those of the Connecticut Valley than do those of other regions considered. The main differences are in the cropping system and the quantity and method of applying fertilizer. Connecticut Valley farmers use five to ten times as much commercial fertilizer as do Wisconsin tobacco farmers, and less manure. Brown root-rot usually causes more damage in Massachusetts than in Wisconsin.

In Lancaster County, the principal tobacco-growing section of Pennsylvania, a three- or four-year rotation is common practice. Wheat and clover or alfalfa are commonly present in the rotation, and sometimes corn is grown. It is generally believed (16) that yield and quality of tobacco are better in the short rotation which omits corn. For tobacco comparatively large quantities of manure are used, and this furnishes the bulk of the applied nutrients. Experiments have shown that when the manure is supplemented with commercial fertilizer both yield and quality of the tobacco are enhanced.

The Connecticut station (1) has reported no experiments with tobacco rotations, but has reported some benefits from the use of cover crops for tobacco in continuous culture. Of several cover crops used, rye, oats, and vetch have produced best results. With respect to cover crops, results in Connecticut agree rather closely with results at this station but different results were obtained from the use of manure. In their experiment manure was found to have a progressively bad effect on yield and quality of the crop, while in the Massaachusetts experiments manure gave the best results. There are several possible causes for this difference. In the Connecticut experiments two to four times as much manure was used as in ours. Furthermore, there may have been a difference in the quality of the manure used in the two experiments, due to different proportions and kind of bedding materials, etc. The manure used in the Massachusetts experiments was mixed horse and cow manure with a comparatively small amount of sawdust, and being from the accumulation of a year in each case, was in a fair stage of decomposition when

applied. The marked increase in the organic matter content reported by the Connecticut workers suggests that decomposition was not very rapid in the soil or else there was an appreciable inert residue. Finally, soil differences may account for some of the discrepancies in results between the two stations.

There is a measure of agreement between the manure experiments of the two stations with respect to the prevalence of black root-rot. In the Connecticut experiment the soil became heavily infested with black root-rot, and the severity of the infestation was considered a strong factor in the decline of yield and quality. In the Massachusetts experiments the manured plots developed slightly more root-rot than did the check plots, but considerably more than those with timothy and red top covers. The average percentage of infected roots for the period 1926-1932 was: Manure, 19.3; no cover (check), 15.0; timothy cover, 7.0; red top, 5.0.

The experimental evidence from other sections of the United States regarding the effects of rotation, cover crops, and manure on tobacco is briefly summarized as follows: In the southern tobacco sections crop rotations give good results. With the exception of the intensive shade-tobacco district of Florida, there is no experimental evidence that continuous culture might not give better results. Under the conditions and practices which generally prevail in the South —soils comparatively low in nitrogen, little fertilizer used and a long growing season — it is likely that the rotation system is the best available. Cover crops have produced variable effects, some having been beneficial and some injurious. In the northern tobacco sections, likewise, effects of cover crops have been variable but on the whole beneficial. Rotations have also produced variable effects. The highest tobacco yields of the United States now are obtained in Pennsylvania, a section in which rotation is the common practice, but here also there is no evidence that the rotation is superior to continuous culture.[5] From Wisconsin, however, there is evidence that rotations containing sod-forming crops are injurious to tobacco, but not so injurious as in Massachusetts (Whately experiments) where more fertilizer was used. In both Pennsylvania and Wisconsin as well as in the southern sections some manure resulting from dairy farming is used for tobacco, and apparently with benefit. In the Connecticut experiments manure reduced both yield and quality, but here much larger quantities were used than in other sections and this in addition to a heavy application of commercial fertilizer.

Summary and Conclusions

Several cropping systems for tobacco either used or suggested for the Connecticut Valley were compared. Results for eight years, 1924-1931, are reported in the preceding pages. Data for the year 1932 are presented in Table 19 of the appendix. Tobacco was grown in continuous culture without a cover crop, with timothy, rye, and red top as cover crops, in two types of rotation, and with manure. In supplementary experiments timothy, corn, potatoes, and onions were grown in alternate years in comparison with tobacco grown continuously. The results and conclusions are summarized as follows:

1. Cover crops as a group gave tobacco of both better quality and higher yield than did no cover. However, there was a difference in the effects of the cover crops used, and only in the case of red top was the advantage of sufficient magnitude to convince one that it was due to the treatment instead of to chance.

2. Besides the agronomic advantages of certain cover crops for tobacco, there

[5] Dr. P. J. Anderson, in a private communication, states that continuous culture of tobacco is not practiced in Pennsylvania because in Lancaster County the soil reaction is so high that black root-rot becomes serious after about the second year, and it is necessary to grow other crops.

is the unmeasurable but real advantage of reducing the wind erosion of soils. In the rather densely populated section of tobacco culture such wind erosion causes dust storms which are a public nuisance and economic disadvantage. Cover crops are a positive help in abating this nuisance. They are helpful also in some cases where water erosion may be serious.

3. The rotation experiments gave results which were quite unfavorable to tobacco, although in most cases the other crops were apparently benefited by having tobacco in the rotation. In a supplementary experiment, it was found that corn and hay were benefited by being alternated with tobacco. When alternated with tobacco, potatoes did better than when grown continuously. Onions, on the other hand did not do well when rotated with tobacco. The mutually unfavorable effects of these two crops appear to be due to the different soil conditions required for best growth of the two crops.

4. Tobacco grown in the animal-husbandry rotations (tobacco, corn and timothy or clover) was so poor in yield and quality as to rule this rotation definitely out of consideration as practicable for the Massachusetts portion of the Connecticut Valley. Results were about equally poor with clover and timothy as the sod-forming crop. The crop index for the rotation which includes timothy was 302.9 compared with 438.4 for the cash-crop rotation, 559.0 for continuous tobacco without cover or manure, and 625.6 for continuous tobacco with a manure supplement. From these results it appears advisable for farmers who wish to run a livestock enterprise in connection with tobacco growing to keep tobacco out of any rotation including corn, timothy, and clover.

5. Associated with the animal-husbandry rotation was an injurious effect on tobacco which manifested itself by producing more or less dwarfed or stunted, spindling tobacco with an abnormally dark green color, and causing abnormal wilting in hot dry weather. This effect or condition of the tobacco is known as brown root-rot, because of the brown, decayed appearance of the roots. This condition was found to vary from season to season. In wet seasons brown root-rot is usually worse than in dry, and may be a contributing cause of the generally low production in this Valley in wet years.

6. Manure as a supplement to fertilizer applied to tobacco in continuous culture was found to be beneficial. Although the yield was slightly lower than that from the red top cover, the quality of the tobacco was so much superior that the crop index was raised appreciably above that of red top. The results of 1932 are even more definitely in favor of the manure supplement.

7. Thus, these experiments present a rather convincing argument for the use of a moderate quantity of manure as a supplement to commercial fertilizer. The advantage from manure lies largely in its effect on quality. The use of a red top cover comes second as a means of producing good quality of tobacco, and is a much more feasible cropping system for most Valley farmers on account of the scarcity of manure. It is quite possible that a combination of the two systems could be worked out, which would include the good points of each, and be suitable for Connecticut Valley farmers.

8. The cropping systems studied in this experiment have produced little or no change in the soil conditions. Continuous culture of tobacco without the plowing in of a cover crop caused the greatest increase in acidity, which was only 0.5 a pH unit. The use of cover crops, the rotation, and manure, tended to stabilize the reaction of the soil. It was only in case of the cash-crop rotation where limestone was used for the benefit of the rotation that the acidity of the soil was reduced.

9. Likewise, the several cropping systems produced hardly perceptible changes in stable or semi-permanent organic matter of the soil. Only in the case of timothy used as a cover crop or in rotation was there any increase in the organic matter which could be assigned to anything more than chance variation. However, it does not necessarily follow that because of a failure to produce measurable permanent changes in the amount of soil organic matter, the added organic matter has not been of value.

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Appendix

Note on Statistical Interpretation of Data

By taking sufficiently wide class intervals it was found that the yield data gave approximately normal distribution curves, and were thus capable of statistical treatment. The mean yield of each plot for the period 1926-1931 was considered as a unit in the calculation of statistical constants. Thus the effect of seasonal variation was eliminated or reduced in a manner suggested by Engledow and Yule.* The following formulae were then used in calculating constants:

$$\text{Standard deviation} = \sqrt{\frac{\Sigma d^2}{n}}$$

$$\text{Probable error of a single plot} = \pm .6745 \text{ standard deviation}$$

$$\text{Probable error of the mean (p. e.)} = \frac{\pm .6745 \text{ standard deviation}}{\sqrt{n}}$$

The following constants were obtained:

Cropping system	Mean yield lb.	Standard deviation lb.	Probable error of single treatment lb.	%	Probable error of the mean lb.	%
No cover (check)	1603	76.0	51.2	3.2	16.2	1.0
Manure	1693	106.6	71.8	4.2	25.4	1.6
Timothy cover	1620	108.5	73.0	4.7	23.1	1.4
Red top cover	1697	65.2	43.8	2.6	19.5	1.1
Rye cover	1624	38.5	25.9	1.6	11.7	.7

In order to see if the difference between any two means was significant, the probable error of the difference was obtained by using the formula:

$$\text{Probable error of the difference} = \sqrt{(\text{p.e.}_1)^2 + (\text{p.e.}_2)^2}$$

To be considered significant, that is due to the treatment and not to chance, any difference must be at least 3.8 times its probable error.

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*Engledow, F. L., and Yule, G. U. The principles and practices of yield trials. Empire Cotton Growing Corporation, London (1930.)

Explanation of the Grade and Crop Index

Grade Index:

In comparing the quality of tobacco grown under different treatments, it is very difficult to keep in mind the percentage of six or more commercial grades of tobacco from one treatment, and compare them with a like number from another. To simplify the comparison use has been made of a grade index* similar to that developed and used at the Connecticut Experiment Station. *The grade index is a single numerical expression for the grading quality* of the tobacco grown under a given treatment, and is comparable, but not equivalent to the average selling price per pound based on percentage of grades. It is based on the percentage of the carefully assorted commercial grades and the relative price value of the different grades. Although market prices vary from year to year, the ratio of prices of the different grades remains fairly constant. The following table gives the commercial grades and numbers denoting relative price values:

Commercial Grade		*Symbol*	*Comparative value*
Light wrappers	(19″ up)	L	1.00
Medium wrappers	(21″ up)	M	.60
Long Seconds	(19″ up)	LS	.60
Short Seconds	(15″ - 17″)	SS	.30
Long Darks	(19″ up)	LD	.30
Short Darks	(13″ - 17″)	SD	.20
Fillers		F	.10
Brokes		B	.10

The grade index is obtained by multiplying the percentage of each grade by the corresponding comparative value and adding the products.

Crop Index:

The crop index is obtained by multiplying the yield in pounds per acre by the grade index of a given treatment. This product is comparable, but not equivalent to the price the farmer might expect to get if he were paid according to the grading of the crop.

*Conn. Sta. Bul. 334, p. 178 (1932.)

TABLE 8 — YIELD AND GRADE OF TOBACCO GROWN CONTINUOUSLY WITH FERTILIZER ONLY.

Year	Fertilizer Pounds per A.	Per Cent of Grades								Grade Index	Yields Pounds Per Acre	Crop Index
		L	M	LS	SS	LD	SD	F	B			
1924	3000	...	....	6.6	4.2	40.4	10.4	21.7	16.7	.234	1316	307.9
1925	3000	...	0.6	20.8	2.6	40.3	6.0	15.6	14.1	.300	1275	382.5
1926	3000	5.0	6.8	20.3	4.5	43.8	2.5	8.8	8.3	.380	1655	628.9
1927	3000	2.4	6.2	27.0	2.9	30.8	7.3	12.3	11.1	.362	1523	551.3
Average 1924-1927		1.9	3.4	18.7	3.6	38.8	6.6	14.6	12.5	.319	1442	467.7
1928	3500	0.6	8.1	26.1	9.5	28.7	9.8	8.8	8.4	.364	1381	502.7
1929	3500	.4	6.9	19.6	8.9	34.4	10.6	10.7	8.5	.334	1498	500.3
1930	3500	7.4	16.0	28.6	6.2	24.4	5.2	4.7	7.5	.457	1873	856.0
1931	3500	3.1	11.0	34.8	9.5	26.9	9.0	3.9	1.8	.440	1687	742.3
Average 1928-1931		2.9	10.5	27.3	8.5	28.6	8.7	7.0	6.6	.399	1610	650.3
Average 1924-1931		2.4	7.0	23.0	6.0	33.7	7.6	10.8	9.6	.359	1526	559.0

TABLE 9 — YIELD AND GRADE OF TOBACCO GROWN CONTINUOUSLY WITH FERTILIZER SUPPLEMENTED WITH MANURE.

1924	3000	...	....	7.5	4.7	48.7	10.6	15.3	13.2	.255	1331	338.1
1925	3000	...	0.8	26.6	3.6	40.0	5.5	12.1	11.4	.330	1323	436.6
1926	3000	5.0	8.2	19.2	3.8	48.2	1.3	7.6	6.7	.387	1763	684.0
1927	2250	6.8	9.0	24.8	4.7	32.7	7.1	8.2	6.7	.412	1550	638.6
Average 1924-1927		3.0	4.5	19.5	4.2	42.4	6.1	10.8	9.5	.346	1492	524.3
1928	2625	3.1	12.7	18.0	11.5	32.5	8.5	7.6	6.1	.379	1439	545.4
1929	2625	1.1	5.1	23.6	10.0	33.7	9.8	9.1	7.6	.352	1658	583.6
1930	2625	13.4	18.5	26.4	5.5	22.0	3.3	3.4	7.5	.504	1998	1007.0
1931	2625	3.3	8.2	36.1	10.0	30.6	8.1	3.3	.2	.441	1750	771.8
Average 1928-1931		5.2	11.1	26.0	9.3	29.7	7.5	5.9	5.4	.419	1711	727.0
Average 1924-1931		1.1	7.8	22.8	6.7	36.1	6.8	8.3	7.1	.383	1602	625.6

TABLE 10 — YIELD AND GRADE OF TOBACCO GROWN CONTINUOUSLY WITH MANURE AND TIMOTHY COVER.

1928	2625	2.0	10.0	24.3	8.9	29.8	11.3	4.9	8.7	.379	1514	573.8
1929	2625	2.1	7.7	25.2	7.1	26.3	9.9	9.4	12.4	.359	1614	579.1
1930	2625	10.2	15.9	26.6	5.8	27.8	3.9	5.4	4.5	.475	1862	884.5
1931	2625	4.2	11.8	29.8	10.1	32.7	7.1	4.3	...	.438	1705	746.8
Average 1928-1931		4.6	11.4	26.5	8.0	29.2	8.1	6.0	6.4	4.13	1674	696.1

TABLE 11 — YIELD AND GRADE OF TOBACCO GRADE GROWN CONTINUOUSLY WITH FERTILIZER AND TIMOTHY COVER.

Year	Fertilizer Pounds per A.	Per cent of Grades								Grade Index	Yields Pounds per Acre	Crop Index
		L	M	LS	SS	LD	SD	F	B			
1924	3000	...	....	2.1	2.1	33.3	27.9	19.1	15.5	.210	1150	241.5
1925	3000	...	0.5	16.4	4.7	30.1	11.8	23.0	13.5	.266	1076	286.2
1926	3000	6.6	7.2	14.3	6.5	45.2	2.6	10.6	7.0	.374	1512	565.5
1927	3000	3.2	7.9	26.3	3.4	29.7	8.8	13.1	7.6	.376	1464	550.5
Average 1924-1927		2.5	3.9	14.8	4.2	34.6	12.8	16.5	10.9	.307	1301	410.9
1928	3500	1.6	5.3	25.4	8.5	32.8	11.3	7.3	7.8	.362	1516	548.8
1929	3500	.4	7.1	21.6	9.3	31.8	11.9	11.7	6.2	.342	1585	542.1
1930	3500	6.8	15.7	27.6	6.3	27.0	6.2	3.8	6.6	.451	1910	861.4
1931	3500	3.0	10.8	34.5	9.9	26.5	9.0	4.2	2.1	.436	1731	754.7
Average 1928-1931		3.0	9.7	27.3	8.5	29.5	9.6	6.8	5.7	.398	1686	676.8
Average 1924-1931		2.7	6.8	21.0	6.3	32.1	11.2	11.6	8.3	.352	1494	543.8

TABLE 12 — YIELD AND GRADE OF TOBACCO GROWN IN NEW TIMOTHY COVER SERIES.

1928	3500	1.2	5.8	23.1	9.5	28.9	12.4	7.7	11.4	.345	1406	485.1
1929	3500	.7	8.6	20.9	9.0	30.2	10.2	11.8	8.6	.343	1560	535.1
1930	3500	6.6	16.4	26.6	6.9	25.4	5.8	5.8	6.5	.446	1901	847.9
1931	3500	2.8	14.2	33.9	8.3	25.1	8.0	4.1	3.7	.440	1736	763.8
Average 1928-1931		2.8	11.3	26.1	8.4	27.4	9.1	7.4	7.6	.394	1651	658.0

TABLE 13 — YIELD AND GRADE OF TOBACCO GROWN CONTINUOUSLY WITH RESIDUAL TIMOTHY COVER.

1928	3500	1.4	4.5	26.3	9.6	31.1	8.7	8.9	9.4	.356	1361	484.5
1929	3500	.7	4.8	18.5	7.8	31.8	11.3	14.1	11.1	.313	1446	452.6
1930	3500	7.9	14.4	28.6	5.8	23.2	5.7	5.7	8.9	.450	1900	855.0
1931	3500	4.4	15.1	32.8	7.0	26.2	8.4	3.2	2.9	.455	1726	785.3
Average 1928-1931		3.6	9.7	26.6	7.6	28.1	8.5	8.0	8.1	.394	1608	644.4

TABLE 14 — YIELD AND GRADE OF TOBACCO GROWN CONTINUOUSLY WITH RED TOP COVER.

1926	3000	5.3	6.6	15.2	5.4	49.7	2.0	10.2	5.6	.369	1585	584.9
1927	3000	2.4	5.2	27.8	2.6	33.0	6.8	13.0	9.2	.365	1623	592.4
Average 1926-1927		3.9	5.9	21.5	4.0	41.4	4.4	11.6	7.4	.367	1604	588.6
1928	3500	1.3	7.8	25.7	7.6	32.9	9.1	6.3	9.3	.369	1551	572.3
1929	3500	.8	7.8	22.7	7.5	36.6	8.5	9.2	6.9	.357	1671	596.6
1930	3500	6.9	13.3	27.1	5.1	26.1	4.1	5.9	11.5	.447	1936	865.4
1931	3500	3.4	15.9	34.2	8.4	25.7	6.6	4.1	1.7	.459	1814	832.6
Average 1928-1931		3.1	11.2	27.4	7.2	30.3	7.1	6.4	7.4	.408	1743	716.7
Average 1926-1931		3.4	9.4	25.5	6.1	34.0	6.2	8.1	7.4	.394	1697	674.0

TABLE 15 — YIELD AND GRADE OF TOBACCO GROWN CONTINUOUSLY WITH FERTILIZER AND RYE COVER.

Year	Fertilizer Pounds per A.	Per cent of Grades								Grade Index	Yields Pounds per Acre	Crop Index
		L	M	LS	SS	LD	SD	F	B			
1926	3000	7.0	7.6	17.8	4.3	44.8	2.5	9.2	6.8	.391	1626	635.8
1927	3000	1.2	6.6	24.8	3.8	33.5	8.0	14.5	7.6	.352	1527	537.5
Average 1926-1927		4.1	7.1	21.3	4.1	39.2	5.3	11.9	7.2	.372	1577	586.6
1928	3500	.9	6.1	24.7	8.8	35.6	9.0	7.1	7.8	.360	1422	511.9
1929	3500	3.3	10.0	18.4	9.7	28.8	11.5	11.8	6.5	.360	1620	583.2
1930	3500	7.7	17.2	25.5	7.3	22.0	6.1	6.0	8.2	.447	1860	831.4
1931	3500	3.7	13.5	33.6	8.9	23.9	10.6	4.4	1.6	.446	1685	751.5
Average 1928-1931		3.9	11.7	25.6	8.7	27.6	9.3	7.3	6.0	.403	1647	669.5
Average 1926-1931		4.0	10.2	24.1	7.1	31.4	8.0	8.8	6.4	.393	1624	641.9

TABLE 16 — YIELD AND GRADE OF TOBACCO GROWN IN ROTATION WITH CORN AND TIMOTHY

1924	3000	...	....	0.5	1.9	23.1	26.6	32.8	15.1	.179	1023	183.1
1925	3000	...	0.3	16.4	4.6	21.3	13.5	28.4	15.5	.249	929	231.3
1927	3000	...	....	5.9	4.9	15.6	14.9	49.1	9.6	.186	1043	194.0
Average 1924-1927		...	.1	7.6	3.8	20.0	18.3	36.8	13.4	.205	998	202.8
1928	3500	0.6	6.0	8.3	6.4	17.3	30.4	17.7	13.3	.255	1254	319.8
1930	3500	...	5.0	12.4	14.4	19.3	25.2	14.5	9.2	.279	1201	335.1
1931	3500	2.7	5.9	21.9	20.7	35.4	9.1	4.1	.3	.383	1446	553.8
Average 1928-1931		1.1	5.6	14.2	13.8	24.0	21.6	12.1	7.6	.306	1300	402.9
Average 1924-1931		0.6	2.9	10.9	8.8	22.0	20.0	24.4	10.5	.255	1149	302.9

TABLE 17 — YIELD AND GRADE OF TOBACCO GROWN IN ROTATION WITH CORN AND CLOVER HAY.

1928	3500	1.2	6.4	9.6	7.8	22.2	28.1	18.1	6.6	.279	1067	297.7
1930	3500	...	8.3	13.2	12.5	21.9	18.2	15.2	10.7	.295	1326	391.2
1931	3500	2.7	13.7	10.2	21.6	36.3	12.6	2.7	.2	.372	1377	512.2
Average 1928-1931		1.3	9.5	11.0	14.0	26.8	19.6	12.0	5.8	.315	1257	400.4

TABLE 18 — YIELD AND GRADE OF TOBACCO GROWN IN ROTATION WITH POTATOES AND ONIONS

1924	3000	...	....	0.9	2.4	28.4	27.1	30.4	10.8	.192	1103	211.8
1925	3000	..	2.1	22.7	3.4	43.4	5.9	15.7	6.8	.324	1357	439.7
1926	3000	2.4	4.1	10.7	7.8	53.1	3.0	14.7	4.2	.320	1426	456.3
1927	3000	...	7.5	15.3	3.2	32.9	11.0	16.4	13.7	.298	1434	427.3
Average 1924-1927		.6	3.4	12.4	4.2	39.5	11.8	19.3	8.9	.284	1330	383.8
1928	3500	.1	5.2	31.0	7.7	28.8	8.4	11.0	7.8	.363	1474	535.1
1929	3500	...	8.6	18.4	12.7	30.1	12.5	13.9	3.8	.333	1354	450.9
Average 1928-1929		.1	6.9	24.7	10.2	29.5	10.5	12.5	5.8	.348	1414	493.0
Average 1924-1929		0.4	5.2	18.6	7.2	34.5	11.2	15.9	7.4	.316	1372	438.4

TABLE 19 — GRADE INDEX, YIELD, AND CROP INDEX OF TOBACCO.

(Summary of Results of 1932)

Cropping System	Grade Index	Yield, Lbs.	Crop Index
Continuous Tobacco:			
No cover (check)	.413	1897	783.4
Manure	.449	1945	873.3
Manure and timothy cover	.390	1806	704.3
Timothy cover	.376	1787	671.9
Timothy cover (residual)	.397	1916	760.7
Red top cover	.413	1907	787.6
Rye cover	.366	1681	615.2
Rotation Tobacco:			
With corn and timothy	.330	1335	440.6
With corn and clover	.282	1407	397.8

TABLE 20 — YIELD PER ACRE OF POTATOES, ONIONS, AND TOBACCO GROWN IN ROTATION.

Year	Potatoes Bushels	Onions Pounds	Tobacco Pounds
1924	226.4	9,960	1,103
1925	363.3	17,450	1,357
1926	296.9	25,100	1,426
1927	201.0	5,766	1,434
1928	291.0	14,845	1,474
1929	229.7	11,933	1,354
Average	268.1	14,176	1,372

TABLE 21 — YIELD PER ACRE OF CORN, TIMOTHY, AND TOBACCO GROWN IN ROTATION.

Year	Ear Corn Bushels	Corn stover Tons	Timothy hay Tons	Tobacco Pounds
1924	26.5	1.23	1.16	1023
1925	74.1	2.86	.75	929
1926	42.1	1.47	.76	....
1927	15.5*	1.12*	1.76	1043
1928	12.0*	1.35*	.96	1254
1929	57.5*	1.58*	1.17	....
1930	57.4	1.89	1.71	1201
1931	58.6	1.61	2.58†	1446
Average	50.5	1.64	1.36	1149

*Corn following timothy and clover — plots not divided for corn yield.
†Fertilizer for timothy increased in 1931.

TABLE 22 — YIELD PER ACRE OF CORN, CLOVER HAY, AND TOBACCO GROWN IN ROTATION.

Year	Ear Corn Bushels	Corn stover Tons	Clover Hay Tons	Tobacco Pounds
1927	45.5*	1.12*	3.92	....
1928	42.0*	1.35*	1.78	1067
1929	57.5*	1.58*	2.74	....
1930	50.2	1.80	1.67	1326
1931	57.0	1.58	2.18	1377

*Corn following timothy and clover — plots not divided.

TABLE 23 — YIELD PER ACRE OF CERTAIN CROPS FOLLOWING OTHER CROPS.

	1925	1926	1927	1928	1929	Average
Tobacco (lb.) following:						
Tobacco	1,301	1,601	1,861	1,406	1,741	1,582
Onions	1,665	1,744	1,930	1,574	1,472	1,677
Potatoes	1,258	1,488	1,930	1,273	1,586	1,507
Corn	1,142	1,383	1,624	1,299	1,349	1,359
Hay	1,545	1,000	1,798	1,274	1,723	1,468
Onions (lb.) following:						
Tobacco	9,100	22,480	7,730	15,921	25,276	16,101
Onions	26,160	27,500	6,510	14,480	26,086	20,147
Potatoes	26,000	17,540	6,391	13,036	20,344	16,662
Potatoes (bu.) following:						
Tobacco	234	223	177	216	151	200
Onions	240	222	172	224	232	218
Potatoes	215	184	130	198	155	176
Ear Corn (bu.) following:						
Tobacco	83.6	33.0	39.1	44.4	42.7	48.6
Hay	58.2	39.8	47.9	45.0	49.2	48.0
Corn	63.0	34.9	41.4	33.2	37.7	42.0
Hay (tons) following:						
Tobacco	1.62	3.36	4.04	2.32	3.63	2.99
Hay	1.86	1.52	3.07	2.39	2.68	2.30
Corn	1.93	.92	3.36	1.06	2.57	1.97

TABLE 24 — PERCENTAGE DISTRIBUTION OF LEAF SIZES IN THE GRADES OF TOBACCO GROWN IN DIFFERENT CROPPING SYSTEMS.

CONTINUOUS TOBACCO

Year	L	M	LS	SS		LD		SD			F	B
	19″ up	21″ up	19″ up	15″	17″	19″	21″ up	13″	15″	17″		
No Cover (Check)												
1924	....	....	6.6	0.8	3.4	18.7	21.6	....	2.2	8.2	21.7	16.8
1925	....	0.6	20.8	.2	2.4	7.8	32.5	....	2.1	3.9	15.6	14.1
1926	5.0	6.8	20.2	1.0	3.5	4.8	39.0	....	.8	1.8	8.8	8.3
1927	2.4	6.2	27.0	.2	2.7	7.1	23.7	0.6	2.2	4.5	12.3	11.1
1928	.6	8.1	26.0	2.5	7.0	10.9	17.9	.7	3.3	5.8	8.8	8.4
1929	.5	6.9	19.6	3.4	5.5	10.2	24.1	1.8	3.6	5.8	10.7	8.5
1930	7.4	16.0	28.7	2.7	3.4	6.2	18.2	.5	1.5	3.2	4.7	7.5
Manure												
1924	....	....	7.5	1.1	3.7	18.9	29.8	....	2.1	8.4	15.3	13.2
1925	....	0.8	26.6	.4	3.2	7.4	32.6	....	2.0	3.5	12.1	11.4
1926	5.0	8.2	19.2	.5	3.4	3.4	44.7	....	.4	.9	7.6	6.7
1927	6.8	9.0	24.8	.6	4.1	7.0	25.6	0.6	1.8	4.8	8.2	6.7
1928	3.1	12.7	18.0	3.1	8.3	10.1	22.6	.4	3.0	5.0	7.6	6.1
1929	1.1	5.1	23.5	3.6	6.4	8.8	25.0	1.3	2.9	5.6	9.1	7.6
1930	13.4	18.5	26.4	2.0	3.5	5.0	17.0	....	1.0	2.3	3.4	7.5
Timothy Cover												
1924	....	....	2.1	0.6	1.5	21.9	11.4	0.1	8.1	19.7	19.1	15.5
1925	....	0.4	16.4	1.0	3.7	10.3	19.9	....	4.3	7.5	23.0	13.5
1926	6.6	7.2	14.3	1.5	5.0	5.7	39.6	....	.6	1.9	10.6	7.0
1927	3.2	7.9	26.3	....	3.4	8.9	20.9	.8	2.8	5.1	13.1	7.6
1928	1.6	5.3	25.3	2.8	5.7	14.5	18.3	.8	3.1	7.5	7.3	7.8
1929	.4	7.1	21.6	3.5	5.9	9.0	22.7	2.2	3.1	6.6	11.7	6.2
1930	6.8	15.7	27.5	2.1	4.2	6.1	21.0	.1	1.6	4.5	3.8	6.6
Red Top Cover												
1926	5.3	6.6	15.2	0.9	4.5	4.8	44.9	....	0.4	1.6	10.2	5.6
1927	2.4	5.2	27.8	....	2.6	7.9	25.1	0.2	2.0	4.6	13.0	9.2
1928	1.3	7.8	25.6	2.4	5.2	11.4	21.5	.5	2.7	6.0	6.3	9.3
1929	.8	7.8	22.7	2.4	5.1	9.3	27.3	1.0	2.6	4.9	9.2	6.9
1930	6.9	13.3	27.1	1.9	3.3	5.5	20.6	.2	1.1	2.7	5.9	11.5
Rye Cover												
1926	7.0	7.6	17.8	1.1	3.3	5.6	39.2	....	0.7	1.7	9.2	6.8
1927	1.2	6.6	24.7	.5	3.4	9.3	24.2	0.3	1.7	6.0	14.5	7.6
1928	.9	6.1	24.6	2.3	6.5	10.9	24.7	.8	2.4	5.9	7.1	7.8
1929	3.4	10.0	18.4	3.4	6.2	10.8	18.0	2.1	3.3	6.1	11.8	6.5
1930	7.7	17.2	25.5	2.9	4.4	7.1	14.9	.3	2.0	3.8	6.0	8.2

ROTATION TOBACCO

With Corn and Timothy												
1924	....	....	0.9	1.0	1.4	22.3	6.2	....	7.5	19.6	30.3	10.8
1925	....	2.1	22.7	.3	3.1	8.2	35.3	....	1.7	4.1	15.7	6.8
1926	2.5	4.1	10.7	2.0	5.8	8.8	44.2	....	.5	2.5	14.7	4.2
1927	....	7.5	15.3	.3	3.0	9.4	23.3	0.3	3.8	7.0	16.4	13.7
1928	.1	5.2	31.0	2.3	5.4	12.6	16.2	.4	3.2	4.8	11.0	7.8
1929	....	8.6	18.5	4.8	7.9	14.1	16.0	1.7	3.0	7.7	13.9	3.8
With Potatoes and Onions												
1924	....	....	0.5	0.6	1.3	16.6	6.5	....	9.0	17.6	32.8	15.1
1925	....	0.3	16.4	1.0	3.6	8.3	13.0	....	6.3	7.2	28.4	15.5
1927	....	....	5.9	....	4.9	8.9	6.7	0.7	6.1	8.1	49.1	9.6
1928	0.6	6.0	8.3	1.1	5.3	12.7	4.5	3.3	11.5	15.7	17.7	13.3
1930	....	5.0	12.4	5.3	9.1	14.1	4.9	5.2	8.6	11.5	14.4	9.2

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE.
4M-6-'33 No. 8732

Figure 3. — A cover crop, as shown in the foreground of this picture, sown on tobacco fields after the crop is harvested, protects the soil from erosion by water and wind. Wind erosion is often severe in the Connecticut Valley, and the "dust" storms, as seen in the background, remove considerable fertile soil in the aggregate.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 298 JUNE, 1933

The Significance of Length of Biological Laying Year in Production Breeding

By F. A. Hays and Ruby Sanborn

High persistency has long been recognized as an important factor in breeding for egg production. In previous studies, however, persistency has been considered only within the limits of the 365-day pullet laying year. The studies here reported were undertaken to discover whether birds that continue to lay without interruption for 13, 14, or 15 months are superior for breeding purposes to birds laying for 9 to 12 months before molting.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE SIGNIFICANCE OF LENGTH OF BIOLOGICAL LAYING YEAR IN PRODUCTION BREEDING

By F. A. Hays, Research Professor, and Ruby Sanborn, Research Assistant, in Poultry Husbandry

Introduction

High persistency as indicated by late molting at the end of the pullet laying year has long been recognized as very desirable from the standpoint of high annual egg production. A review of the literature on this point scarcely seems necessary. Suffice it to note that Hays and Sanborn (1927 c) report a net correlation of $+.7501 \pm .0063$ between annual persistency and annual egg production in Rhode Island Reds at the Massachusetts Agricultural Experiment Station.

This report is concerned with the duration of the biological laying year; that is, the period from first pullet egg to a 30-day cessation of production after March 1. In those birds which did not stop laying for as long as 30 days after they had passed the 365-day production date, the onset of a pause of 8 or more days was considered as the termination of the biological year. In the 12 generations studied there were 11 individuals that showed no cessation of production as great as 8 days at the close of the pullet year, and these were omitted.

The studies reported below were undertaken to discover whether birds that continue to lay without interruption for 13, 14, or 15 months are actually superior for breeding purposes to birds laying for 9 to 12 months before molting. The report is divided into three parts: (1) Correlation studies showing the relation of length of biological year to characters affecting fecundity and to egg production; (2) The relation between the length of the biological year and other desirable characteristics; and (3) The relation between the duration of the biological year in mothers and annual persistency and production of their daughters.

Birds Used for the Study

All birds used were Rhode Island Reds from the Station flock that has been developed since 1913, and include females hatched in the non-broody line, the high-production line, the hatchability experiment, the experiment on variability in production, the experiment on egg size and egg character, and the studies on the relation of intensity to feather color. Twelve generations, hatched in 1917 and from 1920 to 1930 inclusive, were used in Parts 1 and 2. The twelve generations of daughters reported in Part 3 were hatched in 1918 and from 1921 to 1931 inclusive. Two generations were omitted in both cases because the birds were discarded without complete records on account of disease epidemics. Only birds retained for two full laying years are included in Parts 1 and 2.

Part 1. Correlation Studies

The relation of the length of biological laying year to some important inherited characters known to affect egg laying is considered, as well as the relation of length of the biological year to the egg record made during the biological year and the annual egg record. The coefficient of correlation was used to measure the association by tabulating each bird with respect to the two characters being considered. Each correlation was tested for linearity by Blakeman's (1905) test. In those

cases where the difference between the squared values of the correlation ratio and the correlation coefficient was less than three times its probable error, the relation was considered linear and the correlation coefficient alone is reported. When the regression was non-linear, the correlation ratio is used as the measure of association. Only pullet-year records are included in the correlation tables.

1. *Relation Between Age at First Egg and Length of Biological Year.*

The correlation between age at first egg and annual persistency in earlier flocks was reported as $-.6146 \pm .0090$ (Hays and Sanborn, 1926.) In such cases persistency is terminated within 365 days from the date of the first pullet egg. Now the question arises whether the earlier maturing birds are also more likely than the later maturing birds to continue to lay after the termination of the 365-day period.

Records are available on 911 individuals upon which the correlation between age at first egg and length of biological year was calculated.

Number of birds	911
Mean age at first egg — days	190.47
Age standard deviation	$\pm$ 21.32
Mean biological year — days	363.62
Biological year standard deviation	$\pm$43.16
Coefficient of correlation	$-.5661 \pm .0152$

The mean length of the biological year is very close to 365 days. The range for this character was from 80 to 484 days. The standard deviation amounts to 11.87 per cent of the mean, which should not be considered large in view of the combined effects of environment and heredity.

The relation between age at first egg and duration of biological year is linear by Blakeman's test and is therefore measured by the coefficient of correlation. The squared value of this constant is .3193, indicating that about 32 per cent of the variation in duration of the biological year is due to variation in age at first egg. The correlation table also shows that almost 50 per cent of the birds studied had a biological year equal to or greater than 365 days. The correlation coefficient reported here does not differ greatly from that reported by Hays and Sanborn (1926) as the measure of the relation between age at sexual maturity and persistency within the 365-day laying year, namely $-.6146 \pm .0090$. The data indicate that early sexual maturity is rather intimately associated with a long laying year.

2. *Relation Between Winter Pause Duration and Length of Biological Year.*

Winter pause marks a period of non-productivity between the date of the first pullet egg and March 1. The duration of the pause varied from 4 to 113 days in the population studied. Only those birds having a winter pause of 4 days or more are considered in this section. If the winter pause represents a period of recovery for the reproductive system, there may be some relation between pause duration and the duration of the biological year. A total of 494 pause birds are available in the population studied. These were tabulated in a correlation table and the following constants derived:

Number of birds	494
Mean winter pause — days	21.03
Winter pause standard deviation	$\pm$15.19
Mean biological year — days	365.84
Biological year standard deviation	41.37
Coefficient of correlation	$+.1744 \pm .0294$

The correlation between pause duration and length of the biological year is of questionable value since its squared value (.0304) indicates that only about 3 per cent of the variation in duration of the biological year is associated with variation in pause duration. As a selection unit for increasing the length of the biological year, pause duration is of very little value.

3. *Relation Between Winter Clutch Size and Length of Biological Year.*

Mean winter clutch size has been used extensively at this Station as a measure of intensity or rate of laying. Rate of laying is distinctly an inherited character as Hays and Sanborn (1927b) have shown. Correlation studies have been made to discover whether the rate of winter laying shows any relation to the length of the biological year. The constants calculated are as follows:

Number of birds	910
Mean winter clutch — eggs	3.49
Winter clutch standard deviation	$\pm$1.77
Mean biological year — days	363.92
Biological year standard deviation	$\pm$42.19
Coefficient of correlation	+.0590.$\pm$0223
Correlation ratio	.2251$\pm$.0212

Blakeman's test indicates that the regression of biological year on clutch size is non-linear. Hence the correlation ratio measures the association between the two variables. The association is positive, indicating that to some extent the more intense winter layers tend to lay for a longer period than the less intense layers. The squared value of the correlation ratio is .0507, which suggests that only 5 per cent of the variation in duration of biological year is due to clutch size variation.

4. *Relation Between Days Broody and Length of the Biological Year.*

The total number of non-productive days spent in broody periods during the pullet laying year is an indication of degree of broodiness. There is evidence in this flock that degree of broodiness depends upon inheritance. If a broody period serves as a recuperative period for the reproductive system, the anticipated result might be a greater duration of the biological year in the more intense broody individuals. In this study only individuals showing one or more broody periods are included in the correlation table. The constants derived are as follows:

Number of birds	191
Mean total days broody	33.04
Total days broody standard deviation	$\pm$26.28
Mean biological year — days	358.26
Biological year standard deviation	$\pm$50.57
Coefficient of correlation	−.0633$\pm$.0486
Correlation ratio	.2907$\pm$.0447

The extreme variability in degree of broodiness is very striking. The mean is 33.04 days with a standard deviation of 26.28, making the coefficient of variation 79.5 per cent.

The negative coefficient of correlation is statistically insignificant, but the regression is non-linear. The correlation ratio indicates that the more intensely broody birds are likely to exhibit a shorter biological year. The squared value of the correlation ratio shows that about 8.45 per cent of the variation in length of biological year is due to variation in degree of broodiness.

5. *Relation Between Annual Persistency and 365-Day Egg Record.*

The correlation between annual persistency within a 365-day period from first pullet egg and the 365-day egg record has been shown to be intimate in the generations of birds hatched at the Massachusetts Station from 1916 to 1924 (Hays and Sanborn, 1926). This study is repeated using the 911 birds considered in this report. In the earlier report the authors pointed out that the birds were divided into two genetic classes: namely, those laying for a shorter period than 315 days and those laying for 315 days or longer before the annual molt. In this earlier report and in this section the duration of egg production beyond the 365-day limit is not considered. The fact should be noted in connection with these correlation studies that the birds used represent a selected group that was kept for two laying years because of superior pullet-year records. The following constants were derived from the correlation table:

Number of birds	911
Mean annual persistency — days	342.11
Annual persistency standard deviation	± 33.98
Mean annual production — eggs	229.92
Annual production standard deviation	± 32.72
Coefficient of correlation	$+.5798 \pm .0148$
Correlation ratio	$.6257 \pm .0136$

The relation between annual persistency and annual egg production proved not to be linear by Blakeman's test. The correlation ratio shows in this population an intimate association between persistency and production. Its squared value is .3915 indicating that about 40 per cent of the variation in production is associated with variation in persistency. As a unit in selection persistency is of great value.

6. *Relation Between Length of Biological Year and the Egg Record for the Biological Year.*

It is desirable to know whether the egg record during the biological year is intimately associated with the duration of the biological year. In other words, is there high probability that a long period of laying previous to molt is likely to be associated with a high egg record? By tabulating each bird in a correlation for length of biological year and egg production in the same period, the constants below were obtained:

Number of birds	911
Mean biological year — days	363.62
Biological year standard deviation	± 43.16
Mean egg record for biological year	237.52
Egg record standard deviation	± 38.57
Coefficient of correlation	$+.6999 \pm .0114$

Mean egg production during the biological year is 237.52 compared with 229.29 for the 365-day year. The variability of production is also somewhat greater in the biological year. The regression of egg production on duration of biological year is found to be linear. The coefficient of correlation is highly significant and by its squared value indicates that 48.99 per cent of the variation in egg record for the biological year is due to variation in duration of the biological year. This value is highly significant in biological data and attaches considerable importance to the length of the biological year.

7. *Relation Between Length of Biological Year and Annual Egg Record.*

Annual egg record as used throughout this report covers the period from first pullet egg to 364 days thereafter for each individual. It is highly desirable to know whether the bird possessing the ability to lay continuously for more than a year is more likely to be a heavier layer in the first 365 days of production. By tabulating the length of the biological year and the annual egg record of each individual, the following constants were obtained:

Number of birds	911
Mean biological year — days	363.62
Biological year standard deviation	±43.16
Mean annual production — eggs	229.92
Annual production standard deviation	±32.72
Coefficient of correlation	+.4715±.0174
Correlation ratio	.5520±.0155

The regression of production on duration of biological year is found to be non-linear by Blakeman's test; consequently the correlation ratio measures the association between these two variables. The actual value of length of biological year as a selection unit may be determined by squaring the correlation ratio which gives .3047. Stated simply, this means that 30 per cent of the variation in annual production is due to variation in duration of biological year.

In general, the data presented in Part 1 of this report indicate that the ability to lay for a long period of time is desirable from the standpoint of egg production.

Part 2. — Relation of Length of Biological Year to Some Important First- and Second-Year Characteristics

In this part consideration is given to several desirable characteristics not specifically related to first-year egg production but very important in breeding for high fecundity. Further evidence is presented to show whether or not a long biological year may be considered of sufficient significance to take an important place in the breeding program. The length of biological year is considered in relation to first- and second-year hatchability, to body weight at first egg, to body weight at the close of the pullet year, and to second-year egg production.

In the generations used in this report there were 426 birds with complete two-year records. This group was divided into three classes with respect to duration of biological year; those with persistency of less than 315 days; those with persistency ranging from 315 to 365 days; and those with persistency exceeding 365 days.

TABLE 1 — RELATION OF LENGTH OF BIOLOGICAL LAYING YEAR TO HATCHABILITY, BODY WEIGHT, AND SECOND-YEAR EGG PRODUCTION

Length of biological year	Number of birds	Hatchability per cent		Body weight pounds		Second-year egg production
		First year	Second year	At first egg	At end of pullet year	
Under 315 days	26	67.60	72.50	5.53	5.95 (2)*	156.50
From 315 to 365 days	159	78.30	78.21	5.44	5.89 (25)	147.84
Over 365 days	241	71.72	77.35	5.30	6.09 (69)	160.91

*Only a part of the 426 birds were weighed at the close of their laying year. The figures in parenthesis show the number of such birds in each class.

1. *Relation of Length of Biological Year to First- and Second-Year Hatchability.*

The mean hatchability of the three persistency classes during the first and second laying years is shown in Table 1. The data do not show any relation between duration of biological year and percentage of fertile eggs hatched during the period from March 25 to May 15 of each year. Hatchability therefore seems to be independent of those factors concerned with the duration of the laying year. The data do indicate, however, that in general the same individuals have a higher hatching record as yearlings than as pullets.

2. *Relation of Length of Biological Year to Body Weight at First Egg.*

Body weight at first egg is a measurement that may be taken at the beginning of the bird's productive period. The value of such a record as a criterion of later fecundity traits needs to be determined. Body weight of each of the 426 birds was recorded on the day she laid her first pullet egg, and the mean for each of the three persistency classes is shown in Table 1. These data indicate that greater duration of the biological laying year is associated with a smaller body weight at first egg. This smaller body weight at first egg has been shown by Hays (1933) to be an explicit function of age at first egg.

3. *Relation of Length of Biological Year to Body Weight at the Close of the Pullet Year.*

Only a part of the 426 birds considered in sections 2 and 3 were weighed at the close of their laying year, the number being 96. These meager data are presented (Table 1) to furnish a small amount of information on the relation between body weight at the close of the 365-day laying year and duration of biological year. These weight records were taken on a date averaging 365 days after the first pullet egg for the birds housed together.

The data suggest that birds with heavy weight at the close of their 365-day production year are more likely to continue to lay than are smaller individuals. In other words, birds that lay at the expense of body weight are likely to lay fewer eggs as Hays (1932) pointed out, and they are also likely to have a shorter productive year.

4. *Relation of Length of Biological Year to Second-Year Egg Production.*

In the Rhode Island Red flock of the Massachusetts Agricultural Experiment Station, the mean second-year production amounts to about 70 per cent of the first-year production. Second-year records on this flock are begun immediately at the conclusion of the 365-day record. By this system of records the second-year record of a bird with a biological year of 365 days or more is penalized, in that all of the non-productive period usually accompanying molt falls in the second laying year. On the other hand, individuals with a short biological year show a part of the molt period at the close of the 365-day first-year record and a part in the beginning of the second-year record. The fact should also be noted that late molting reduces the length of the molt period as Hays and Sanborn (1930) and Marble (1930) have pointed out.

The second-year egg records of the 426 birds studied are shown in Table 1. The differences in mean annual egg records are not great for the three groups. In general, the data indicate that great length of the first biological year is likely to be followed by a higher second-year egg record than might be anticipated if the duration of the first biological year falls below 365 days.

Part 3. — The Inheritance of Persistency

High persistency has been reported by Hurst (1921) to be inherited as a recessive trait in White Leghorns and White Wyandottes. He measured high persistency by the ability to lay at the rate of 30 per cent from July 1 to the close of the laying year, no birds being considered high in persistency unless they laid for at least 50 days after July 1. This period would end on August 19 as the earliest date. Using Hurst's dividing age between early- and late-maturing birds at 270 days, the absolute length of the biological laying year for the highly persistent birds would be about 9 months or 270 days.

Hays and Sanborn (1926) report that the Massachusetts Station flock shows two general classes with respect to duration of the laying year — those laying for less than 315 days and those laying for more than 315 days. Hays (1927a) presented evidence to indicate that the ability to lay for 315 days or more depends upon a dominant autosomal gene P.

This part of the report is concerned with the ability of dams to transmit persistency to their daughters. The obvious weakness of such a study lies in the fact that genetic records of the sires are not available. In a general way, however, the data will be useful to show whether or not selection of dams alone for duration of biological year increases the length of laying year in resulting daughters.

Twelve generations of daughters consisting of 2311 individuals are included from 427 dams that had been retained in the flock for two or more full laying years. These dams are the birds that have already been considered in Parts 1 and 2. They are divided into three classes with respect to duration of their biological year. In tabular form are presented the number of dams and daughters concerned, together with the daughters' mean annual persistency records and their mean annual egg records and the mean annual egg record of the dams.

Table 2 — Relation of the Length of Biological Year of Dams to Their Annual Egg Production and to their Daughter's Annual Persistency, Annual Egg Production, and Laying House Mortality.

Length of biological year of dams	Dams		Daughters			
	No.	Annual production Eggs	No.	Annual persistency Days	Annual production Eggs	Mortality in laying house Per cent
Under 315 days	26	201.38	124	320.02±3.62	195.89	36.40
From 315 to 365 days	159	236.69	879	325.60±1.28	201.49	26.55
Over 365 days	242	245.10	1308	330.75±0.99	207.24	27.76

Table 2 shows that in the selection of breeders emphasis was laid on length of biological year so that the number of dams concerned in the low class is small, and the majority fall in the group with a biological year greater than 365 days. The mean annual egg records of the dams are also closely associated with the length of the biological year.

Daughters' annual persistency includes the productive period from first pullet egg either to the onset of a 30-day cessation of production after March 1 or to the end of the 365-day laying year. It is evident that this method of calculating persistency does not take cognizance of the actual persistency of birds that lay beyond the 365-day period. The difference in mean annual persistency of classes 1 and 2 is 5.58±3.84, and of classes 2 and 3 is 5.15±1.62. The data therefore show no significant difference in the mean annual persistency of daughters from dams with a biological year of less than 315 days and those from dams with a biological year

of 315 to 365 days. Daughters from dams with a biological year greater than 365 days show a significantly higher mean annual persistency than do daughters with a shorter biological year. Mean annual first-year egg records of daughters from the three presistency classes of dams increase with the persistency of the dams.

These data indicate the general superiority of birds with a long biological year over birds with a shorter biological year in breeding for high fecundity.

The mortality in the laying houses is distinctly higher for the daughters from dams with persistency records below 315 days. The mortality of daughters from dams with persistency between 315 and 365 days and from dams with a persistency greater than 365 days is essentially the same. These facts indicate that high persistency is a partial measure of vigor which is one of the vital essentials in successful breeding.

Progress Throughout the Experiment

Chart 1 presents graphically the mean annual persistency of daughters by generations throughout the experiment. Class 1 represents the daughters from dams with a biological year under 315 days; Class 2, the daughters from dams with a biological year of from 315 to 365 days; and Class 3, the daughters from dams with a biological year greater than 365 days. Data are not available for the hatching year of 1919 and 1920.

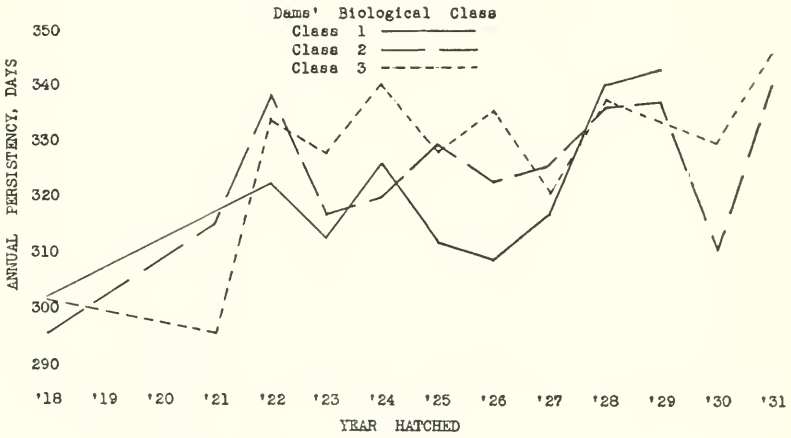

Chart 1. Annual Persistency of Daughters by Years.

In general, there is a progressive increase in the annual persistency of daughters from year to year. For the most part the daughters from the two classes of dams with superior length of biological year excel the daughters from dams with a biological year under 315 days. There is an apparent advantage from the standpoint of annual persistency in selecting female breeders whose biological year exceeds 365 days. The high trend in the solid line in 1928 and 1929 has little significance because it represents the daughters from but four dams in 1928 and one dam in 1929.

Chart 2 presents the mean yearly egg records of daughters from the three classes of dams with respect to length of biological year. Here again there is progressive increase throughout the experiment in daughters of dams that belonged to the

two upper classes with respect to duration of biological year. The egg records of daughters from dams with short biological year did not increase up to 1927, and the last two yearly means are not significant because of small numbers. The superiority of the egg records of daughters from dams with a biological year exceeding 365 days appears to warrant the selection of such birds for breeding to increase fecundity.

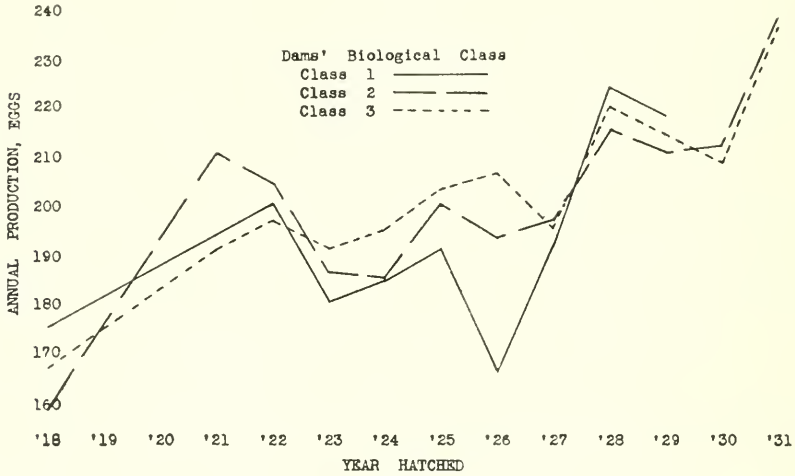

Chart 2. Annual Egg Production of Daughters by Years.

Summary

A study is made on 911 Rhode Island Red females of twelve generations that were trapnested for two full laying years and on a total of 2311 of their daughters representing twelve generations.

1. Duration of biological year is intimately associated with early sexual maturity.

2. There is no significant relation between duration of winter pause and length of biological year.

3. Large winter clutch size or high intensity shows a small but significant positive correlation with length of biological year.

4. Degree of broodiness shown by the number of nonproductive broody days gives a negative correlation with duration of biological year.

5. Annual persistency shows an intimate correlation with annual egg record.

6. The egg record for the biological year is intimately correlated with the duration of the biological year.

7. First- and second-year hatchability are independent of duration of biological year.

8. Small body weight at first egg is associated with great length of biological year.

9. Heavy body weight at the close of the 365-day laying year is associated with greater duration of biological year.

10. Second-year egg production tends to be higher in birds showing a biological laying year greater than 365 days.

11. Annual persistency of daughters from dams with a biological year greater than 365 days is distinctly higher than in daughters from dams with a biological year of from 315 to 365 days or from dams with a shorter biological year than 315 days.

12. Annual egg records of daughters from dams with extended biological year are superior to those from dams with shorter biological year.

13. Great duration of biological year in dams indicates superior vigor as measured by the lower mortality rate for their daughters in the laying houses.

14. In general, the selection for breeding purposes of females having the ability to lay continuously for more than 365 days is a commendable practice.

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Publication of this Document Approved by Commission on Administration and Finance.
3M-6-'33 No. 8737

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 299 OCTOBER, 1933

Shipping Massachusetts Apples to Out-of-State Markets

By A. H. Lindsey and A. A. Brown

The development of apple orchards in New England and especially in Massachusetts has made it desirable for the grower to find markets outside of the immediate production area. Shipping is the phase of marketing around which this study is developed. The volume of apples grown, preparatory and supplementary marketing practices, distribution among markets, and marketing experience have all been considered primarily from the relationship which they bear to shipping.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

SHIPPING MASSACHUSETTS APPLES TO OUT-OF-STATE-MARKETS

By A. H. Lindsey, Professor of Agricultural Economics, and A. A. Brown[1]

Introduction

Increasing total and commercial production of apples in Massachusetts, without a proportionate increase in home consumption, points to the necessity for expanding the consuming area. Growers are already shipping apples to New York City, and a few have tried other cities outside of New England. Their experience has brought home to them the need of more information about transportation and market facilities, if these cities are to become regular outlets for their crop. This study was therefore undertaken to assemble and make easily available to growers facts which may help them solve the problems which arise in shipping their fruit.

Method

Approximately 100 leading Massachusetts apple growers were interviewed in order to secure original data. The experience of these growers in shipping their apples by various methods and under different conditions was made the basis for the study of comparative transportation costs.

Information on transportation questions was secured from local, central, and off-line representatives of both originating and delivering railroad carriers. Data were also obtained from the various tariffs of the participating lines.

Data on markets were assembled by correspondence with railroad agents, chamber of commerce officials, federal and state marketing representatives, and managers of produce terminals.

Adequacy of Data

Although but 100 growers were interviewed and only 73 reports were used, the results seem adequate, for these growers produced 51 per cent of the total commercial crop in Massachusetts in 1931. In Table 1 growers are grouped according

TABLE 1—APPLE GROWERS IN MASSACHUSETTS CLASSIFIED ON THE BASIS OF 1931 PRODUCTION

Production Range in Bushels	Number of Growers
0 - 1,999	9
2,000 - 3,999	22
4,000 - 5,999	11
6,000 - 7,999	9
8,000 - 9,999	4
10,000 - 14,999	12
15,000 - 19,999	2
20,000 or over	4
Total	73

[1]Graduate Assistant in Agricultural Economics.

to volume of production. In Table 2 are listed the quantities of the principal varieties produced by growers in each group.

The information on rail transportation is reliable. Carriers are required to publish tariffs of rates and charges for supplementary services as well as regulations covering the types of service which they can perform. Statements herein presented are correct as of February 1, 1933. Since changes occur frequently in the tariffs it is desirable that growers check currently with the railroad those parts of the bulletin which apply to their shipments.

Data pertaining to truck shipments were secured from the growers. This is the only accurate method. General trucking information is inadequate because publicity of rates or services by truck operators is not required.

Data on the markets are not as detailed as would be desirable, due to the fact that it was necessary to collect the data by correspondence.

TABLE 2—RELATIVE IMPORTANCE OF VARIETIES ON THE BASIS OF VOLUME OF COMMERCIAL PRODUCTION, 1931

Production Range in Bushels	McIntosh (bushels) 67 reports	Baldwin (bushels) 60 reports
0 - 1,999	3,105	3,640
2,000 - 3,999	26,942	14,446
4,000 - 5,999	19,500	11,414
6,000 - 7,999	15,050	10,700
8,000 - 9,999	15,646	7,140
10,000 - 14,999	68,587	24,713
15,000 - 19,999	11,500	2,800
20,000 or over	66,516	60,500
Total	226,846	135,353

Special Problems Confronting Massachusetts Apple Growers.

The population of the United States increased more than 17 millions between 1920 and 1930. Forty-nine per cent of this increase was north of the Ohio and east of the Mississippi. The data available show that there has been no discernible increase in the consumption of apples within this area. On the basis of carlot unloads, as reported by the United States Department of Agriculture, there has actually been a slight downward trend; but when the movement by motor truck is added to the rail unloads the data show that total consumption is practically unchanged. It appears, therefore, that apple consumption is not keeping pace with increase in population. In fact, the consumption of apples has not increased in the last decade. In contrast, there has been a marked increase in the use of other fruits.

This situation presents a serious problem. All growers of apples might ask themselves why their product is not holding its own in the markets. Has the saturation point been reached in apple consumption? Is it indifference to proper merchandising on the grower's part which prevents apples from meeting with favor among buyers? Are the retailers shifting consumers' demand? If it is desirable that all apple growers consider the situation, it is particularly pertinent for the Massachusetts grower.

Increase in Local Production

To aggravate a generally unfavorable situation, Massachusetts is one state in which production is expanding. Of a total of 2,159,120 trees in 1925,[2] 756,897 or 35 per cent were not of bearing age; 248,000 or 11.5 per cent were over 29 years of age. In 1931[3] the total number of trees was 1,716,000, of which 585,000 or 34 per cent were 8 years of age or less. The number of trees over 30 years old varied from 11 to 14 per cent depending upon the total used; while 20 to 25 per cent of the trees were from 9 to 13 years old.

The large percentage of young trees gives reasonable assurance that any decrease in production which results from cutting down old trees will be more than offset by the 9- to 13-year-old trees coming into full bearing. The high percentage of trees less than 9 years old furnishes a sound basis for expecting an increase of 30 per cent in total annual yield during the next decade. If efficiency in orchard and harvesting practices continues at its present high level, over 75 per cent of this increase will be of commercial importance.

Commercial production is influenced constantly by improvements which growers have made and are making in their orchard and harvesting practices. Increase in the percentage commercially produced concurrent with a larger total production will increase more than proportionately the volume of locally grown apples available for the market.

Among the changes in methods which enable the grower to place a larger percentage of his crop on the market are the growing of fewer varieties and the production of cleaner fruit. Table 3 shows the tendency of Massachusetts growers to concentrate on fewer varieties. Cleaner fruit is promoted by the "Ninety Per Cent Clean Apple Club." The growth of the commercial crop in relation to the total crop in Massachusetts is shown in Table 4.

TABLE 3—TREES IN MASSACHUSETTS APPLE ORCHARDS, PERCENTAGE DISTRIBUTION BY VARIETY AND AGE

	1925 [1]		1925-1927 [2]
Variety	Bearing	Non-Bearing	Plantings
Baldwin	45.2	29.5	23.9
McIntosh	19.2	31.9	31.5
Wealthy	5.9	8.0	5.7
Delicious	1.5	8.9	7.3
Gravenstein	4.7	5.7	2.4
Cortland	....	....	6.5
Other	23.5	16.0	22.7
Total	100.0	100.0	100.0

[1] Yount, H. W. and Jefferson, L. P., An Economic Study of the Massachusetts Apple Industry. Mass. Agr. Exp. Sta. Bul. 228, P. 111, Table V.

[2] Plan for Making Apple Industry of Massachusetts More Profitable, Ext. Ser. Bul. Annex. 1932. M. S. C.

[2] Youngman, Statistics and Charts of the Apple Industry, p. 10. U. S. Dept. Agr. Bul. Agr. Econ. March, 1930.

[3] U. S. Dept. Agr. Yearbook 1931, p. 719.

TABLE 4 — TREND OF COMMERCIAL APPLE PRODUCTION IN MASSACHUSETTS, 1917-1932. (THOUSANDS OF BUSHELS).

Year	Total	Commercial	Per Cent of Total
1917[1]	2,163	675	31.2
1918	2,430	900	36.9
1919	3,187	1,005	31.5
1920	3,575	1,125	31.4
1921	1,125	516	45.8
1922	3,010	1,383	45.9
1923	3,300	1,800	54.5
1924	3,360	2,025	60.2
1925	3,160	1,965	62.1
1926	4,100	2,640	64.3
1927	2,520	1,590	63.1
1928	2,700	1,714	63.4
1929[2]	2,440	1,557	63.8
1930	4,389	2,808	63.9
1931[3]	1,575	1,098	69.6
1932[4]	3,442	2,430	70.5

[1] Youngman, Statistics and Charts of the Apple Industry, p. 28, 1917 to 1928.
[2] U. S. Dept. Agr. Yearbook, 1932, p. 696. 1929-1930.
[3] U. S. Dept. Agr. Crop Reporting Board, Crop Report as of September 1, 1932.
[4] U. S. Dept. Agr. Crop Report, Annual Revisions, December, 1932.

Ways of Meeting the Problem

The above combination of factors which indicates an enlarging production of apples in Massachusetts is significant. Orchards were planted under the assumption that the product could be marketed profitably. Data on consumption indicate that consumers are not eating additional quantities of apples. Massachusetts apple growers must either supply a larger percentage of the total local consumption or promote sales in other consuming areas.

Economically it would appear desirable for New England to supply a larger part of its own needs. In this case fewer outside apples would come into New England and her growers might not have to seek outside outlets. It would require considerable publicity to induce New England people to eat only New England apples. It would also require a very close and complete organization of growers sufficient to control production and price policies. Such an organization seems improbable at this time. The only alternative is for New England growers to enlarge the consuming area and enter markets not now exploited by them.

Present Markets

The larger part of the Massachusetts apple crop is consumed locally. Cities in Massachusetts and the city of Providence, Rhode Island, are the chief outlets. Small towns adjacent to the growers' orchards are of little importance.

New York City absorbs much of the supply from Western Massachusetts, plus a small volume from other apple growing sections within the state. The number of local growers who are actually acquainted with the outside markets is small. Frequently a small volume of local apples is shipped to Pittsburgh or Cleveland.

Occasionally a car is shipped to Cincinnati. Shipments in most of these cases have not been promoted by the growers but by buyers or dealers. These cities which have been regarded as emergency outlets may become regular outlets for some growers in the future.

With reference to the number of markets which a grower used, it was found that 47 per cent sold in one, 18 per cent in two, and 5 per cent in three. Of the men who used but one market 75 per cent sold in Boston and 15 per cent in New York. Large citites were the chief outlets for the main crop. Nearby towns were places in which to sell early varieties, old varieties or odd lots.

The outlets favored by growers regardless of the number used showed that 51 per cent sold in Boston, 28 per cent in New York and 14 per cent in Springfield and Providence.

Except in southern New England, the geographical location of the apple grower had but little influence on his choice of market. Within this area, however, growers sold in whichever one of four cities - Springfield, Worcester, Boston, Providence — was nearest to their orchards.

The data indicated that in general local growers were acquainted with few outlets and few growers were acquainted with outlets outside of New England.

Potential Markets

Included in the group of cities which are potential consuming centers are eight of the ten which rank first in population according to the United States Census of 1930[4]. In addition to having an apparent capacity for absorbing apples, these cities are relatively near by.

The markets which appear to offer the best opportunities for absorbing a supply of Massachusetts apples are:

New York	Baltimore	Cleveland
Philadelphia	Washington	Detroit
Pittsburgh	Cincinnati	Indianapolis

With the exception of New York, which is a potential market for some growers and a regular outlet for others, not more than 5 per cent of the growers are acquainted with the markets suggested.

Certain other cities located in the Northeast have not been mentioned because of certain factors which make them less desirable outlets for New England apples. Buffalo, for instance, is adjacent to an apple-growing region; St. Louis and Chicago are too distant unless prices are particularly good; Montreal is unfavorable because of customs duties.

The volume of Massachusetts apples unloaded in both groups (with the exception of New York) during the period for which figures are available varies from none in 1926 and 1928 to 119 cars in 1930. The unloads are irregular and sporadic. It is probable that buyers on these markets know as little about Massachusetts apples as growers in Massachusetts know about the markets. Data are lacking on recent shipments to these potential markets.

New York City is an exception in that information on traffic to this area is adequate. Data were secured on shipments in 1932 from various points in Massachusetts. In addition to data on rail traffic, it was possible to secure trucking charges so that a comparison of costs by kinds of carriers can also be made.

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[4]U. S. Census, 1930. Population. Vol. 1 p. 18.

Current Harvesting and Marketing Practices of Growers

Before the Massachusetts apple growers attempt to reach the more distant markets they will have to make certain changes in present harvesting and marketing practices, because of the necessity of shipment by rail. Certain other practices as they are now carried on will fit very well into the exploitation of these new markets.

Among the unfavorable items are the size of shipments, the frequency of shipments and the type of package.

At present most of the apples are consigned in lots of two sizes, 100 to 125 boxes and 200 to 300 boxes. Considering 60 shipments for which this type of data is available 21 per cent of the growers shipped in lots of 100 to 125 boxes, 26 per cent in lots of 200 to 300 boxes, and 13 per cent in carloads (600 boxes). In part the size of the consignment is determined by the quantity which can be most efficiently packed out daily by the grower. There is also a definite relation between the type and capacity of the carrier and the size of consignment. In some instances the number of boxes shipped depends on the capacity of the carrier, and in others the selection of the carrier depends on the volume which a shipper wishes to move.

The frequency with which shipments are made seems to affect the size of individual consignments. In the 100 to 125 box group, growers consigned daily. In the 200 to 300 box group, they shipped three times a week. The practice followed is determined partly by the grower's organization and partly by the requests of the consignee.

Another practice which may prove temporarily detrimental to the interests of the grower is the use of the Massachusetts Standard Box. The package is not well known outside of New England. This feature in itself need not be a permanent hindrance. It is no more difficult to handle than the Western box, and is equally well adapted to the display of apples.

Among the factors which can expedite rail shipping into the potential markets are grading, time of sale, and the channels of trade.

Massachusetts growers may be relied on to place on the market a pack which, on a quality basis, compares favorably with packs from other regions. Eighty-seven per cent of the growers graded their Baldwins and McIntoshes, the two varieties which comprise the larger volume of out-of-state consignments. Grading usually means that only the higher priced apples will be shipped. The cost of shipping is consequently less in relation to the price received.

The period of the year when growers normally sell their apples has a direct bearing on shipping. Its importance is further emphasized when considered in relation to the size of consignments and the frequency with which they are made.

About 15 per cent of the growers sold all their McIntosh as picked or shortly after. Practically none sold Baldwins until January first. Most of the sales were distributed throughout the late fall and early winter. It would be possible, therefore, during the normal sales period, to pack out a large enough volume for consignment to a new market. The opportunity exists for organizing the packing force so as conveniently to load out the volume at the proper time. Since most of the sales take place after the peak of harvesting has passed, more attention could be given to satisfactory packing and shipping.

In shipping to any one of the suggested markets, the practice is to consign to a commission house or auction agent. This involves little that is new. Most growers are now selling through the commission house. Markets may differ as to

the manner of reporting sales or the performance of supplementary services. The principal features of dealing through the commission house are well understood.

Current practices favoring the shipping to new markets seem to outweigh the unfavorable ones. A good quality pack, distribution of sales, and much experience in selling through the normal channels of trade are assets. The size and frequency of consignments are not too great a hindrance. They may be adjusted. The time and distribution of sales makes this possible.

Transportation of Apples

Shipping is the phase of marketing around which this study is centered. The volume of apples grown, preparatory and supplementary marketing practices, distribution among markets and marketing experience have all been considered primarily in relation to shipping.

The problem of transportation was studied in particular since it is basic to planning the future expansion of apple production in Massachusetts and New England. Information was secured on the following subjects relative to the transportation of the 1931 crop: Responsible agent, method of shipping, size of consignments, time in transit, destination of shipments, factors considered in selecting the carrier, damage to consignments, and costs involved.

In addition to the data pertaining to the 1931 crop, further information was collected from growers, rail carriers, chambers of commerce, the United States Department of Agriculture, and state marketing officials regarding the problem of shipping to the potential markets for Massachusetts apples.

Current Shipping Practices

The responsibility for shipping the 1931 crop practically rested with the individual grower. Among those producers whose returns can be used, 74 per cent claimed authority for engaging the carrier and giving such instructions as seemed necessary; 18 per cent assigned this responsibility to the buyer; 6 per cent handed the function over to their agents, one of whom was a commission house.

Trucks carried 95.2 per cent of the 1931 apple crop of these growers. The railroads got 4.8 per cent of the traffic. Of the growers, 56 per cent trucked for themselves, 30 per cent used local truckmen[5], and 14 per cent hired commercial truckmen. Most of those in the last group came out from the markets and hauled the loads in. One made a return trip to a market daily past the orchard of a grower; the truck was empty, and the operator was glad to get the return haul. There were also a few selling agents who furnished the trucks or who hired the trucking done.

Among the growers who did their own trucking, 41 per cent also hired some done. A noticeable practice was the engaging of a commercial truckman for the long-distance hauls. Occasionally this supplementary service was employed at the peak of the picking season when the grower's truck could not handle the volume or was being used in the orchard.

As a measure of the distance to which apples were shipped by truck, time in transit for the truck appears to be the best unit. It is the total time which elapses from the departure of the grower from the packing house until he returns that determines whether or not he will make the haul himself. On the nearby

[5] Resident in the same or an adjacent town.

hauls, where he can get into the market and home again in half a day or less, the grower usually operates his own truck. Seventy per cent of the trucks made the round trip in less than six hours.

Fifteen per cent of the trucks were on the road from six to twelve hours. Some of these were grower operated and some were hired. Fourteen per cent of the trucks made overnight trips *one way*. In all instances these trucks were hired.

The growers were questioned as to why one kind of carrier was used in preference to another. Although in a few instances answers were made with much feeling. the favorable attitude towards trucking was commonly based on sound reasons,

The matter of careful handling is the important consideration. Statistically this factor does not stand in first place but ranks second. Some growers neglected to suggest careful handling as a factor to be considered when choosing a carrier, since they probably assumed that this was an accepted principle. In addition to handling apples carefully most of the growers were seeking to reduce the amount of handling necessary. When truckmen pick up the apples at the packing house and deliver them at the door of the commission house, ordinarily at least one handling is eliminated and perhaps two. Trucks are also supposed to carry the apples with less jarring. This, however is open to question. For the bruising which the fruit may receive when a car is added to or cut out of a train there is a corresponding amount of bruising which the apples may get as the trucks drive over unevenly surfaced roads.

It is possible to assign responsibility for damage when the truckman is the carrier. At the loading point this raises no difficulty even when the railroad is the carrier. The shipper (grower) is on hand to insure proper care in loading in both instances. It is when the consignment is delivered that responsibility for damage is hard to place. If a rail shipment has been badly bruised — but no packages broken — and there has been, in addition, cartage to a commission house from the delivery track, there is little possibility of placing the responsibility. If the same lot had been bruised on a through carriage by truck, the operator could be charged with carelessness. The personal relationship between the grower and the truckman is favorable to shipping by truck, particularly when a local truck operator is employed.

The highest percentage of growers preferred the truck to the refrigerator car, because the shipping charges were lower. For the size of the units shipped this was probably true. These lots would, on a rail shipment, take a less-than-carlot rate, which would be sometimes a few cents more or less than the trucking rate per box. The rail carload rate per box is substantially lower than the trucking rate. In this comparison no allowance is made for additional items such as loading, icing, unloading, switching, carting, etc. The problem of shipping charges is considered later.

With reference to relative costs of shipping in hired trucks or hauling in their own trucks, some growers were undecided. The general opinion was that on long hauls commercial truckmen perform the service for much less than the grower can do it. On the short hauls, so far as total cost[6] is concerned, a few growers were of the opinion that they could hire the trucking for less than they could do it themselves. The fact of owning a truck was occasionally sufficient reason for using it for hauling.

Growers shipped by rail for the following reasons: The service was good, dis-

[6]Cash plus depreciation, time, etc.

tance to the market necessitated it, the receiver requested a rail shipment, and a long distance shipment could be more cheaply made by rail.

Shipments were chiefly in lots of two sizes: the small lot ranging from 50 to 125 boxes, and the larger from 200 to 300 boxes. The smaller lot was used by 34 per cent of the growers; the larger by 26 per cent. In addition 13 per cent of the apples were shipped in carloads (600 to 800 boxes).

The small lots were carried usually in grower-owned trucks if the transit time was less than six hours; otherwise in hired trucks. A few of the larger lots were hauled in grower-owned trucks but the rule was to hire the trucking done, since only a few growers owned trucks large enough to carry 300 boxes of apples. Here also the time element partly determined whether the grower used his own truck or not.

Trucking Charges

Data on truck charges paid in 1931 and 1932 were collected. The figures for 1931 were secured by interview; those for 1932, through correspondence with the growers. In 1931 the rate per box from points in Massachusetts to Boston varied from less than 5 cents to 12½ cents. A 10-cent rate commonly applied regardless of distance. Some apples were carried for that rate from as far west as the Connecticut River. In general, however, few growers west of Worcester shipped to Boston. In the eastern apple growing section a few growers paid 12 cents a box, one 8, and one less than 5 for having apples trucked to Boston. On baskets only one figure was secured and that was from a grower west of Worcester. He paid a 15-cent shipping charge to Boston.

Truck rates to Providence showed much more variation than those to Boston and seemed to bear some relationship to distance. Unfortunately the cases from which data were secured are few. The extremes on rates per box were 5 cents and 17½ cents. The shipper who was farthest from Providence paid the highest rate and the one nearest paid the lowest. Other growers paid rates approximately commensurate with the distance.

Truck rates to Springfield ranged from 6 cents to 12 cents per box. The lower rates were hardly indicative of a typical haul since they were in reality part of a through rate to New York.

In the fall of 1931, the usual rate per box from points in Massachusetts to New York City was 20 cents. It was fairly uniform over the entire state. As would be expected, higher than normal rates were charged for small lots and lots from out-of-the-way places.

In 1932, two general rates applied. A 20-cent rate per box was paid by growers in the eastern part of the state and in the northern section of the western part. The rate from towns bordering the Worcester-Springfield highway and in the southern part of Hampshire County was 15 cents per box. Sixty-six per cent of the growers paid 20 cents per box; 24 per cent, 15 cents; 5 per cent, 22½ cents; and 5 per cent, 25 cents per box for trucking to New York. The rates applying from various points in Massachusetts to New York are listed in Table 5.

There was ordinarily but one charge (rate per box times the number of boxes) when the apples were carried by truck. Exceptions applied on lots which were placed in cold storage. When fruit was stored at Springfield prior to selling in New York two trucking charges were made; one from the farm to Springfield, the other from Springfield to New York. A slightly different arrangement governed lots held in cold storage at Boston. On going into storage the usual rate which ap-

plied from the farm to Boston was charged. If the lots at the time of sale were carted from cold storage to the commission man's sales room a cartage fee of 5 cents per box was paid. If the lots, as frequently happened, were sold in cold storage the cartage fee was not directly paid by the grower.

TABLE 5. — RATES QUOTED BY RAILROAD AND BY TRUCK COMPANIES FROM POINTS IN MASSACHUSETTS TO NEW YORK CITY
(CENTS)

Shipping Point	Railroad (per cwt.)[1] 1931 & 1932	Truck (per box) 1931	Truck (per box) 1932	1932 Truck Rate Calculated to cwt. Basis
Ipswich	32	—	20	44
Groton	30	20	20	44
Westford	30	—	25	55
Ayer	29	20	20	44
Stow (West Acton)	30	—	20	44
Gleasondale	30	—	20	44
Sterling Junction	29	20	20	44
Warren	27	—	20	44
Brookfield	27	—	15	33
Belchertown	25	20	15	33
Amherst	26	26	15	33
Williamsburg	24[2]	—	15	33
Greenfield	27	—	20	44
Shelburne Falls	27	—	20	44
Charlemont	27	28	20	44
Pittsfield	28[2]	—	20	44
Williamstown	26	35	22.5	49.5

[1] Carload rate to Barclay Street.
[2] Does not apply to Barclay Street but to the Bronx.

Rail Charges

Forty-four reports on sales of rail shipments were available and were analyzed to determine the accuracy of transportation charges. Several returns could not be used because they were incomplete.

The charges made and the number of accounts on which the charge appeared are shown below:

Charge	*Number of Accounts*
Freight	All
Terminal Freight	11
Storage in Transit	4
Reconsignment	9
Lighterage	9
Bunker	9
Cartage	1
Insurance	14
Assorting	20
Auction Labor	18
Other	5

Returns indicated that the "freight charge" might include freight only or the sum total of charges, except commission, deducted by the selling agent. Of the accounts which included freight only, 17 were slightly incorrect. Ten of these accounts were erroneous in that a rate of 25 cents instead of 26 cents per hundredweight was charged. The other 7 showed slight discrepancies which could be accounted for if a box or a barrel was two pounds above or below the average weight. In tabulating the data these 17 accounts were omitted.

On the remaining 27 accounts, the sum of overcharges plus undercharges amounted to $520.64. Twenty-four accounts showed freight overcharges to growers totaling $488.78. Three accounts showed undercharges of $31.86. The apparent net freight overcharge was $456.92. The range on the twenty-four accounts was from $3.74 to $63.96 per car. The average was $19.03. The undercharges showed a narrower range, $8.78 to $12.24 with an average of $10.62.

Further analysis reveals that the apple grower was not as grossly mischarged as would appear. Nine accounts included lighterage and reconsignment and possible bunker charges under freight. In order to secure deliveries by the carrier indicated, reconsignment and lighterage were necessary. Other deliveries by the same carrier had included bunker charges and, considering the date of shipment, this charge might rightly be made. Deducting the average bunker charge and applying the correct lighterage and reconsignment charges, the overcharges are reduced to $306.32.

Terminal freight as an accounting classification is also indefinite as to what it includes. Eleven receipts listed "terminal freight" charges which totaled $178.07 or an average of $17.09 per car. Ten of these charges were for or included reconsignment. Four charges were for moving cars to and from storage at a storage-in-transit point. Deducting the sum of these charges leaves but $40 chargeable to terminal freight. All other carrier charges were definitely allocated. The remaining charges are marketing costs which can apply regardless of the carrier.

The practice of reporting all charges as freight or terminal freight is to be criticised. It gives the grower an exaggerated idea of the freight cost. It hinders his knowing for what service he is paying. It prevents his changing his shipping order since he has no notion of what might be eliminated or changed.

Criticisms of rail shipments by the growers pertained to (1) extra charges; (2) variations in charges. Extra charges may be of two kinds; those incident to shipping or transportation, and those incident to selling or supplementary services.

Charges made by the railroad are for payment of services *ordered* performed. The railroad does not move a car to or from storage, does not reconsign a car, does not give a car second placings, or perform other additional services except when asked to do so by the shipper or his appointed agent.

Those costs which apply to selling or performing supplementary functions are added at the request of the commission man or other sales agent. Most of the growers give their sales agents practically full power to direct the handling of the fruit.

Variations in charges for equal volumes shipped from the same point to the same destination may arise from several causes. In the first place, there may be slight differences in weights per box or per barrel. A small difference per package makes a noticeable difference in the weight of a car containing 600 to 800 boxes. There may be errors in rate quotations. If a grower keeps his freight bill these can be

checked. The principal source of variation is "errors in commission", that is improper allocation of charges by the sales agent. It should be apparent that similar shipments made under similar conditions to the same destination should move at the same charge. If one sales report lists each charge by items and the second report groups several items under "freight" or "terminal freight" it is natural that the grower should wonder why his shipping charges vary.

Opportunity for dissatisfaction is also afforded by the form in which the sales agent makes his report. On it are listed the payments made to various agencies with no accompanying vouchers. The result of this practice is to stimulate the grower's distrust of carriers and sales agents.

Comparison of Truck and Rail Rates

The only data collected on which to base a fair comparison between truck and rail rates were on shipments to the New York market. In order to get the actual trucking rate paid, the data were obtained from the growers. No attempt was made to secure rates from trucking companies against which to check the charges secured from growers. It is conceded that truck operators quote charges to fit the situation, hence any figures given by them would be of little value in this study.

Certain differences in practice must be recognized before a reasonably sound comparison between charges assessed by railroads and by trucks can be made.

First, the unit on which the charge is based. Railroads quote rates in cents per hundred pounds: - viz., Amherst, Mass., to Barclay Street, New York City, 26 cents per hundred pounds.[7] Truck operators quote rates in cents per box or package: - viz., Amherst, Mass., to New York, 15 cents per box. A box of apples, however, weighs approximately 45 pounds.[8] Two and a fifth boxes weigh 100 pounds; in other words the truck operator's rate from Amherst to New York is 33 cents per hundred pounds. The last column of Table 5 shows the converted truck rate per hundredweight.

This railroad rate is effective only when apples are shipped in car lots with a minimum weight of 24,000 pounds, or about 540 boxes. The railroad rate on less than carloads is approximately twice the carload rate; for example, from Amherst to Barclay Street, it is 52 cents per hundred pounds. The rate per box by truck ordinarily does not vary with the size of the load, unless the load consists of only a few packages.

Another difference which must be considered pertains to the application of the rates. Rail rates apply from definite points in Massachusetts to definite destinations in New York City. The groupings of towns which the railroads use in establishing rates are few. For the most part rail rates are established on a point to point basis. On the contrary, truck operators evidently had but one group of towns from which to develop rates in 1931 and but two groups for 1932. It would seem that the boundaries of the groups vary to meet the situation.

The computed savings per car (derived from Table 6) on shipments by rail are net. Barclay Street deliveries are given overnight service. Apples can be shipped in ventilator cars without ice provided they are not out of storage. Except in particularly inclement weather even apples out of storage may be loaded in ventilator cars and arrive in good condition. There is then no bunker or icing charge.

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[7] Boston and Maine origin.

[8] Corbett, R. B. and Christopher, E. P., "A Study of Apple Containers." R. I. Agr. Expt. Sta. Bul. 227, 1931.

No charges are made for the loading or unloading of rail shipments. At Barclay Street the unloading service is performed by railroad employees at no cost to the shipper.

No charge for loading was included because this varied under different conditions. If the car was loaded at a time when farm labor and equipment were otherwise idle, the cost was negligible. If the loading was done when picking was at its height a charge of $5 to $10 might well be added to the computed cost of shipment by rail.

The charges collected for moving 600 boxes of apples by rail from points in Massachusetts to the various stations in New York are given in Table 6. The cost of shipping an equal volume by truck is indicated in the last column.

TABLE 6. — CHARGE FROM STATIONS IN MASSACHUSETTS TO STATIONS IN NEW YORK CITY (600-BOX LOTS)

Shipping Point	Freight to New York Terminals	By Rail Total Charges[1] to: Barclay Street	Pier 27 28, 29	Duane St., Pier 20	By Truck to New York Total
Ipswich	$86.40	$86.40	$108.90	$127.80	$120.00
Groton	81.00	81.00	103.50	122.40	120.00
Westford	81.00	81.00	103.50	122.40	150.00
Ayer	78.30	78.30	100.80	119.70	120.00
Stow	81.00	81.00	103.50	122.40	120.00
Gleasondale	81.00	81.00	103.50	122.40	120.00
Sterling Junction	78.30	78.30	100.80	119.70	120.00
Warren	72.90	72.90	95.40	114.30	120.00
Brookfield	72.90	72.90	95.40	114.30	90.00
Belchertown	67.50	67.50	90.00	108.90	90.00
Amherst	70.20	70.20	92.70	111.60	90.00
Williamsburg	64.80	64.80	87.30	106.20	90.00
Greenfield	72.90	72.90	95.40	114.30	120.00
Shelburne Falls	72.90	72.90	95.40	114.30	120.00
Charlemont	72.90	72.90	95.40	114.30	120.00
Pittsfield	75.60	75.60	98.10	117.00	120.00
Williamstown	70.20	70.20	92.70	111.60	135.00
Littleton	81.00	81.00	103.50	122.40	120.00
Boston	81.00	81.00	103.50	122.40	——

[1]Total charges include Freight, Reconsignment and Lighterage charges. The two latter are the same for all the shipping points, but differ with the destination as follows:

	Reconsignment	Lighterage
To Barclay Street	None	None
To Pier 27, 28, 29	$6.30	$16.20
To Duane Street, Pier 20	6.30	35.10

Rail Carriers Serving Massachusetts Apple Areas.

Massachusetts apple growing sections are served by four railroads. Some sections are served by more than one railroad. Shippers in the Nashoba belt and the northern part of Worcester County are served by both the Boston and Maine and the New Haven. The former road covers a somewhat wider area than the latter.

In Essex County shippers are served exclusively by the Boston and Maine, those in Plymouth County solely by the New Haven. In the southern part of Worcester County the New Haven is the principal carrier, with a few growers receiving service from a branch of the Boston and Albany. The growers in "Apple Valley" in Franklin County are served by the Boston and Maine, as are those in Williamstown; those in Hampshire County by the New Haven, the Boston and Maine and the Central Vermont railroads.

Most of the growers have easy access to a rail carrier.

Freight Tariffs Applying to Apples

Apples take a fifth class rate[9] in carload lots with a minimum weight of 24,000 pounds. This class applies both to apples in packages and to those shipped in bulk. In computing the freight charge on apples shipped in barrels, the weight used is 160 pounds.[10] Apples shipped in boxes take the actual weight. The joint rates between points in Massachusetts and New York are governed by the New England Freight Association's "Joint Class Rate Tariff, applying in either direction between stations in New England and New York."

The joint rates between points in Massachusetts and the other cities in which the outside markets are located are each governed by a New England Freight Association joint tariff of class rates. The rates as published in these tariffs apply only when shipments are made in accordance with the exceptions specified in the tariffs of the different railroads carrying the shipment and in accordance with routing instructions as given in the routing guide of the originating railroad. Adherence to routes as published in routing guides of originating carriers is necessary if shipments are to receive the benefit of through rates.

It is desirable for the shipper to designate the delivering carrier so that the railroad on which the shipment originates can give it the fastest route. There are literally dozens of routes a shipment may follow to some of the markets in the territory east of the Mississippi and north of the Ohio River.

All standard routings are published by the rail carriers in routing guides. Some routes may be more expensive in terms of total freight cost than others. The freight rate between two points may be the same, yet the total freight charge may be radically different. Once the delivering carrier is determined the most economical route to be used in reaching that carrier is of utmost importance.

As an example of the importance of routing, the following case may be cited. A carload of apples originated on the Boston and Maine in northeastern Massachusetts and was destined Erie Pier delivery in New York City. Routing orders were to be given by the commission man from New York. These orders were not given until the car had passed Troy and had been transferred to the New York Central. Properly routed the car should have proceeded via West Shore Railroad to Weehawken. After passing Troy the car could not be transferred to the West Shore. The shipment reached the 60th St. yard of the New York Central in New York. The connection of the New York Central with the Erie in the New York switching area is at Weehawken on the New Jersey side. To reach Weehawken involved

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[9] Consolidated Freight Classification, No. 6. Interstate Commerce Commission Official Classification 50, P. 214, Item 27.

[10] Exceptions to Official Classification, Boston and Maine, Interstate Commerce Commission, A2677, P. 27, Rule 205. Weight applies regardless of true weight. Exceptions to Official Classification, New Haven, Interstate Commerce Commission, F3270, P. 27, Rule 220.

the use of a car float across the Hudson. Here the car was delivered to the Erie. But the Erie fruit terminal pier is on the New York side, so the car was floated back across the Hudson by the Erie Company. These two floatage movements cost more than the freight charge from Massachusetts to 60th St. yard. As a result the total freight bill amounted to 223 per cent of the freight rate from the point of origin in Massachusetts to New York City.

A circumstance like the one just cited might easily destroy the shipper's margin of profit. Routings may be obtained from the local agent of the railroad. Any routing should be checked to see that it will give the minimum freight charge. In the last section of this bulletin on potential markets, minimum cost routings may be found.

Incidental Services Offered by Rail Carriers

Most rail carriers offer shippers a choice of several routes over which a car may move under the through rate. The combinations are fixed and are published in the Routing Guides of the various roads. For delivery at some markets, selection from as many as fifty different routes may be made. Representative standard all-rail routings are listed with the descriptions of market facilities.

A differential all-rail routing may be used on traffic moving to a few cities. The shipments move in part over a Canadian road. The time in transit via this type of routing is supposedly twenty-four hours longer. To compensate for this slower service the rate applicable is lower than over a standard all-rail routing. On apple shipments the rate is commonly 2 cents per hundredweight less.

Occasionally a grower might find it advantageous in a market where two or more produce terminals operate to switch a car from one to the other. The railroad performs this service under the provisions of tariffs regulating the handling of produce in the particular city. The charge varies with each market. Usually one free movement to a private siding is permitted. Other movements involve at least a reconsigning charge of $6.30 per car. In the discussion of the markets used as illustrations, the actual switching charge applicable is noted.

If it is desirable to change the delivering carrier after the car is rolling, the car may be diverted. The order requesting diversion should be filed with the local agent before the car passes the diversion point. The charge for this service is $2.70 per car. Before requesting diversion, the grower should find out through the local agent where the car is and whether or not it can be diverted under the through rate plus the diversion charge.

The supplementary services of diverting, reconsigning and switching are made available so that growers may market their shipments more advantageously. For growers in Massachusetts the need of these special services is not as great as it is for growers farther from the markets. Their utilization by local producers is apt to be for the purpose of meeting an unusual situation. The railroads are ready to meet the request. The change in orders requires varying degrees of additional work from the railroad. The locating of cars, the changing of billing instructions, etc., are services for which the shipper (grower) should expect to pay.

Relative Advantages Among Producing Areas

The freight charge is the largest of the costs incident to the actual handling of apples and reflects most markedly the favorable position which growers in one region have over those in another. Refrigeration charges are an appreciable item

particularly on apples from the west. Shipments from this area usually move under standard refrigerator service for which the charges are higher than for "icing". Differences in refrigeration costs between producing areas and northeastern markets are negligible except in the case of shipments from the far west. Some small local variations occur in costs of loading, packages and packaging. In determining the relative advantages of producing areas in supplying certain markets, freight charges computed on the cost of shipping a car of 600 boxes, western type, were used.[11]

If an attempt were made to construct a total marketing cost, exclusive of commissions, items would be introduced which would make the comparison of questionable value. The freight charge, however, as a basis of comparison is sound. It is relatively stable; it can be accurately determined; it lends itself well to this type of work, particularly when the distances between areas are large enough so that points of origin and destinations are grouped.

The advantage of the lower freight charges which Massachusetts growers enjoy as a result of being near the consuming areas is wider in its application than is normally appreciated. Large advantages accrue from lower freight charges on shipments not only to Boston or New York, but also to many other markets in the northeast.

A comparison of the freight charges from Massachusetts points to certain markets with the corresponding charge from the far west to the same destination emphasizes the advantageous location of Massachusetts growers. To nearby points such as New York, local growers pay $250 to $272 lower freight charges per car than California, Oregon or Washington growers pay. To more distant points, for example, Cleveland, the difference in favor of Massachusetts growers varies from $221 to $232. Table 7 lists the advantages arising from lower freight charges which Massachusetts growers enjoy over West Coast growers.

A comparison of charges from Massachusetts points with those from the apple regions of New York State to eastern markets shows the advantages of situation to be about evenly divided. To markets such as Cleveland, Cincinnati and Detroit the advantage is generally with New York State.

TABLE 7—DIFFERENCES IN FREIGHT CHARGES TO CERTAIN MARKETS FROM THE WEST COAST AND FROM MASSACHUSETTS SHIPPING POINTS

Market	Range Of Advantage From Massachusetts Points	
New York (Barclay St.)	From $251.10	to $272.70
Philadelphia	245.70	259.20
Baltimore	234.90	245.70
Washington	232.20	243.00
Pittsburgh	213.30	240.30
Cincinnati	197.10	207.90
Cleveland	221.40	232.20
Detroit	213.30	224.10
Chicago	186.23	202.50
St. Louis	159.30	180.90

[11] Shipments from the West Coast move under a commodity rate. The minimum volumes which can be shipped to take this rate are roughly 700 or 800 boxes, depending on the size of the refrigerator car.

Apple growers in the Shenandoah region have an advantage (ranging from $5 to $50 per car) in all the markets under discussion except New York City.

Terminal Facilities in Potential Markets

Detailed information concerning terminal facilities was obtained for seven markets. This information was secured through correspondence with various city organizations and by contact with railroad representatives. These cities may be regarded as the best prospective markets for New England apples. The information should be helpful in assisting growers to make more satisfactory shipments to these consuming centers.

New York

Among the heavy consuming areas to which Massachusetts growers are shipping and to which they may expect to ship increasing amounts is New York City. Characteristics which tend to make it a favorable consignment point are its capacity to absorb volume, its relative nearness to local producing areas, the exceptionally good highways which encourage shipping by truck, and the market facilities provided by railroad companies.

From the viewpoint of adequate facilities for handling rail shipments, this market ranks among the best. There are several produce terminals, all owned by the railroads. The Barclay Street station of the New York Central is the only one in the Washington wholesale and jobbing market district to which Massachusetts growers may ship under protection of the through rate.[12] Other stations in New York to which a through rate applies from points in Massachusetts are the 33d Street terminal for New York Central Railroad delivery of lots originating Boston and Maine or Boston and Albany; pier 29, East River, for lots originating on Central Vermont; and the Bronx Produce House and Pier 37, East River, for shipments originating on the New Haven.

The principal produce terminals, Pier 20 on the Erie and Pier 27, 28, 29 on the Pennsylvania, do not receive shipments from Massachusetts under the through rate. The additional cost for consigning to these stations is discussed elsewhere. (Table 6, p 14).

The choice of stations is dependent primarily on the railroad which serves the shipper. Occasionally, if prices warrant, the location of the consignee's place of business may be the factor governing destination.

It is important to note the necessity of consigning cars to a receiver at a definite point in New York; viz., Green & Company, Barclay Street, and not just Green & Company, New York. The following excerpt is from Pennsylvania Railroad Tariff 1426A, Interstate Commerce Commission 940, Page 4, note 1.

> There are no stations known as New York or Brooklyn and by reference to Rule 25 of this tariff you will note car lot traffic for which shipping order or Bill of Lading does not show a specific station must be receipted and carded and billed to Greenville Piers or Manhattan Piers, N. J., permitting proper delivery to be made by the agent in charge.

This note is of particular application to shipments taking Pennsylvania Railroad delivery at New York. It emphasizes the need for exercising judgment and care in consigning to this market.

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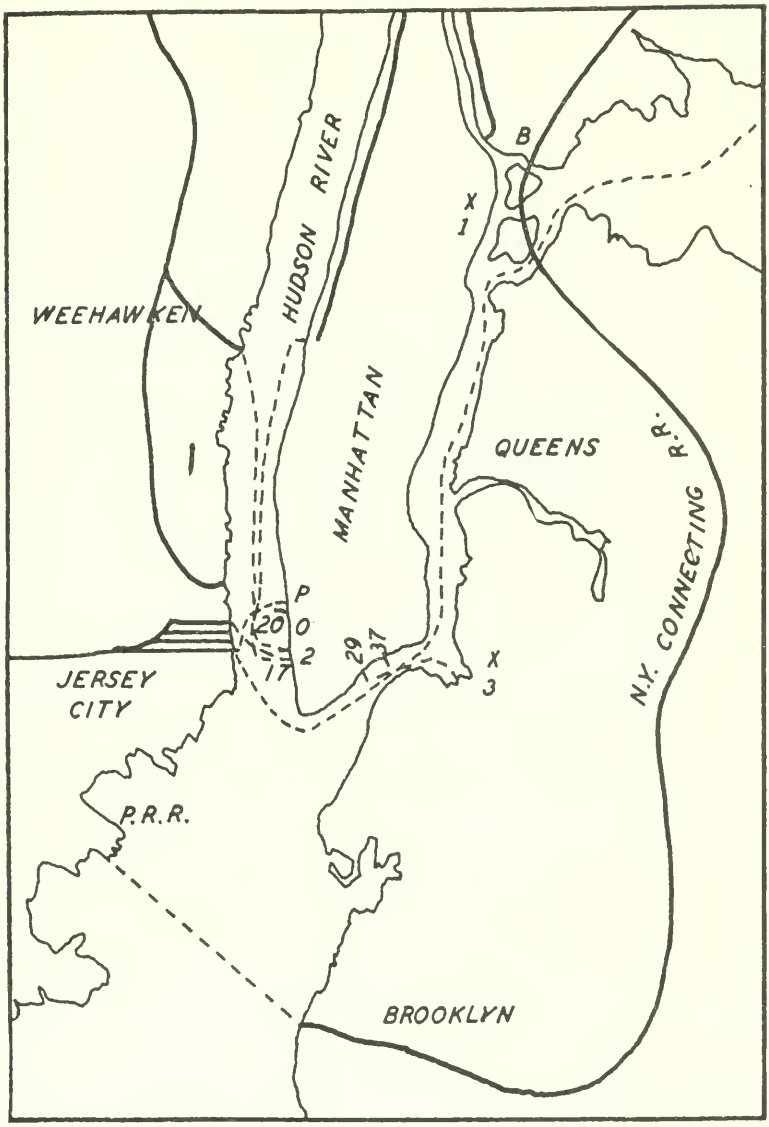
[12]Car must originate Boston and Maine or Boston and Albany.

Railroad Produce Terminals in the New York Market.



Markets
O—Jobbers

X—Wholesalers and jobbers.
1. Harlem
2. Washington
3. Wallabout

Terminals
North River
P—Pennsylvania. Piers 27, 28, 29.
20—Erie. Duane St.
17—New York Central. Barclay St.

East River
29—Central Vermont
37—New York, New Haven and Hartford
B—Bronx

A part of New York has been designated as the New York Harbor Lighterage limits. Handling of traffic within this area is done under provisions in the New York harbor tariffs of the several carriers. The tariffs specify that "Fruits, fresh" shall not be contracted lighterage free. Regulations governing substitution of float service for lighterage are provided as are also exceptions which may apply. The local shipper need not be concerned over the multiplicity of regulations applying in this area. For the most part they will not concern him except when he has stored apples at Jersey City to be sold later at one of the points in the market area.

There are no reciprocal switching arrangements in the New York terminal district. The rates for performing the service vary, depending on which carrier performs it. Between Weehawken and New York City points over West Shore or New York Central[13] facilities it is 3½ cents per hundredweight or 76 cents per ton net or gross as rated. From Jersey City to Pier 20 for Erie delivery the rate is 13 cents per hundredweight. This charge also applies for traffic carried by the Erie for delivery in the New York terminal area by the New York Central.[14] From Jersey City to Pier 27, 28 and 29 over Pennsylvania Railroad facilities the rate is 6 cents per hundredweight. In addition to each of the charges there is a reconsigning charge of $6.30 per car.

Whether or not charges will be made for unloading depends on the delivering carrier and the receiver. At Barclay Street the receiver unloads the car. He may or may not directly charge for the service. At Pier 27, 28 and 29 the Pennsylvania unloads the cars free. In unloading for auction, however, the consignments are assorted according to marks, sizes, etc. For this grouping into lots there is a charge of $2.35 per car.[15] On sales reports received by Massachusetts shippers there was listed an "auction labor" charge of $3.50. Probably the unloading charge was included in that sum. The difference may have been paid to "directors" who are employed by the auction company for directing the stacking.

At the Erie pier the arrangement is similar to that at the Pennsylvania. When the cars are unloaded and the packages placed in one stack there is no charge. For separating the packages into grade, sizes and marks the railroad charges $2.35 per car.[16]

Routings to New York are very simple once the station is designated. The following arrangements are illustrative:

Barclay Street or 33d Street Delivery	*Bronx Produce House or Pier 37 East River delivery*
B&M origin: NYC or WS	NH all the way
B&A origin: NYC or WS	B&M origin: NH

Pier 29 East River
CV all the way

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[13] Interstate Commerce Commission. N. Y. C. 15379, P. 62, rule L. 40.
[14] Correspondence with Erie.
[15] Correspondence. P. R. R.
[16] Correspondence, Erie.

Philadelphia

The facilities in Philadelphia are relatively new and should expedite the distribution of produce. There are two produce terminals both owned by railroads. The Baltimore and Ohio-Reading terminal is used principally in the distributing of California and Florida citrus fruits. With the exception of these citrus fruits, it is estimated that most of the fruits and vegetables consigned to Philadelphia are received at the Pennsylvania terminal.

The Pennsylvania terminal offers practically any type of service the shipper desires. It is essentially a three unit plant; an auction building, two private sales buildings, and a cold storage plant. In addition there is a set of team tracks provided with platforms which are used for display and inspection. There are overhead canopies so that weather conditions do not interfere with business.

The arrangement of buildings is exceptionally favorable for shippers who desire to hold their apples in cold storage. The cars are placed on the tracks of the cold storage plant immediately on arrival. The apples are unloaded at no additional cost to the shipper. When the packages are later moved from cold storage to the sales rooms there is a small charge. At the time of writing, this fee was one cent for boxes and bushels and 3 cents for barrels. Movement at this rate was allowed one way only.

Routing of shipments to Philadelphia is a relatively simple procedure. In any combination one might expect the Pennsylvania to be the delivering carrier.

Pennsylvania Terminal Delivery	*B&O-Reading Terminal delivery*
B&M origin: NH:PRR or D&H:PRR	B&M origin: NH:CRRNJ:Reading or D&H:CRRNJ:Reading
B&A origin: D&H:PRR or WS:D&H:PRR	B&A origin: WS:CRRNJ:Reading
NH origin: PRR	NH origin: CRRNJ:Reading

Shipments from Massachusetts will receive second morning delivery in Philadelphia.

There is no special problem with regard to switching. One free movement can be made within switching limits to private sidings. Additional switching will be done under the provisions of the switching tariff applying at the time the service is performed.

Washington

This city differs from many in that it lacks a modern produce terminal house for the handling of perishables. Like some of the other cities, Washington has no central market district. There are two markets of importance; one known as the Patterson Tract, the other known as the Southwest Market. From the information available it appears that the districts are of equal importance. Each seems to have a porportional share of the patronage of the dealers. Each claims to be well located with respect to consumer trade.

The Patterson Tract Market is operated by the Union Terminal Company and is served by the Baltimore and Ohio Railroad. The railroad does not enter the tract. Its facilities are conveniently located at the Eckington yard a short distance away. The yard is equipped with team tracks for handling produce and several tracks have been set saide for handling this special class of goods. Not far from the tracks served by the Baltimore and Ohio siding are the warehouses of several large food distributors. Among this group are Sanitary Grocery, Atlantic and Pacific and the American Stores, Inc.

The Southwest Market is not operated by any specific agency. Rail service into the market is furnished by the Pennsylvania Railroad. The district is fairly close to many of the larger hotels.

No switching agreements exist between the Baltimore and Ohio and the Pennsylvania Railroad.

The approximate time required for shipments to reach Washington is two to three days, depending upon the originating carrier, location of shipping station on the line of a carrier, routing, etc.

The following list of routings is illustrative of the combination of carriers for giving delivery.

Patterson Tract	*Southwest Market*
B&M origin: NH:B&O	B&M origin: NH:PRR or D&H:PRR
NH origin: B&O	NH origin: PRR
B&A origin: WS:B&O	B&A origin: NYC:D&H:PRR or D&H:PRR

Pittsburgh

Facilities for handling apples at Pittsburgh are adequate. In the produce district, both the Pennsylvania and the Baltimore and Ohio have terminals for handling perishables. Of the two roads the Pennsylvania offers the more complete service. Its terminal comprises team tracks, an auction house and a package delivery house. The Baltimore and Ohio has only team track facilities.

No regulations govern the receipt or handling of apples at the Baltimore and Ohio yards; nor are any unloading charges assessed by the railroad. Consignees make sales directly from the car and for that reason do their own unloading.

Pennsylvania Railroad tariff 1472-E (as of date) governs the handling of fresh fruits at its Pittsburgh terminal. It provides, with specific exceptions, that only bulk perishables will be handled at the team tracks; boxed apples must be handled through either the auction or the package delivery house. The owner or consignee may have either the railroad or some other agent unload the car. If the railroad is to perform the service, the consignee or owner must inform the railroad prior to arrival of the car.

Three handling charges apply at the Pennsylvania terminal. For unloading a car a charge of 50 cents per ton is made. On a car of 600 boxes this would amount to about $7.00. If the consignment is to be assorted into marks, grades, sizes, etc., an additional fee of $2.50 per car is applied. These two charges are made by the railroad. All packages are delivered from the location on the platform to the tailboard of vehicles which cart them away. For this service the Terminal Delivery Company charges $5.00 per car. The total handling charge at the Pennsylvania terminal will range then from $12.00 to $14.50 per car.

If, after a car arrives at either the Pennsylvania or the Baltimore and Ohio terminal, the owner desires to switch to the other, a minimum charge of $25.00 per car is made. In addition, there is a reconsigning fee of $6.30.

Shipments to Pittsburgh are en route about two days. Whether or not they receive second or third morning delivery depends on the point and time of origin.

The following list of routings is illustrative of the different combinations of carriers performing service on Pittsburgh consignments.

Pennsylvania delivery

B&M origin: D&H:PRR or NH:PRR

B&A origin: WS or NYC: PRR or D&H: PRR or NYC:D&H:PRR

NH origin:PRR

Baltimore and Ohio delivery

B&M origin: D&H:DL&W:B&O or NH:CSD:B&O

B&A origin: NYC:B&O

NH origin: CSD:B&O

Cincinnati

"The Cincinnati market is a rather split-up affair. The old jobbing section..... is near the center of the city. They have a nice new auction and office building a mile or so away at the railroad and about half way between are the team tracks—no terminal yet....."[17]

This description indicates that the market is not centralized. With regard to rail shipping there are two districts about a half mile apart. The fruit auction terminal, to which reference is made above, is owned and served by the Southern Railway. It is operated by the United Fruit Auction Company. Sales of citrus and deciduous fruits are held here. Consignments of local apples could be shipped for sale through this outlet. Consignments not being sold at auction are handled in the team track district. The Baltimore and Ohio, the Cleveland, Chicago, Cincinnati and St. Louis (Big Four) and the Pennsylvania are the principal delivering carriers. For a number of years the Baltimore and Ohio Railroad Plumwood Yard has been a center of trade in fruit and vegetable traffic.

A large volume of fruit is consigned direct to chain store warehouses which are served by private sidings. Deliveries are made to them under reciprocal switching agreements.

Reciprocal switching agreements exist among the carriers so that delivery can be made by the Southern Railway at its auction terminal at no additional cost to the shipper. No switching agreements are in effect among the carriers giving team track service; consequently any movement of apple shipments among them will be governed by the tariffs in effect at the time. The possibility of a situation of this kind arising is practically nil.

No published unloading or cartage charges exist. Each consignee makes his own arrangements for these services.

Possible standard routings on shipments to Cincinnati are as follows:

B&M origin: D&H:DL&W:B&O or NYC:CCC&ST.L or D&H:PRR

NH origin:CSD:B&O or PRR

The time in transit is about three days. A car might arrive in time for the market of the third day; it certainly would be ready for a fourth morning market.

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[17] W. E. Piper in the Report of the 37th Annual Meeting of the Massachusetts Fruit Growers' Association, Inc., 1931.

Cleveland

Cleveland is well equipped with facilities for handling produce. The trading is probably centered at the Northern Ohio Food Terminal (N.O.F.T.) which is made up of a market district, an auction building and team tracks. The trade has its offices in the market district, which is composed of four units. The auction building is adjacent to the district and also to the cold storage warehouse.

The N.O.F.T. is served exclusively by the New York, Chicago and St. Louis (Nickel Plate). This line has, however, entered into switching agreements with the Pennsylvania, the Baltimore and Ohio, the Wheeling and Lake Erie, and the Erie so that cars may arrive at Cleveland via these carriers and be delivered to the terminal by the New York, Chicago and St. Louis at no extra cost to the shipper. There is no switching agreement between the New York Central and the Nickel Plate. Cars arriving at Cleveland via the New York Central can be placed at the N.O.F.T. at an additional charge of $12.50.

In addition to the N.O.F.T., the team track facilities of the New York Central are available to shippers of apples. These are located at the Orange Avenue terminal of the New York Central, about one-half mile from the central distributing district.

Under general conditions routings should be combinations which will give New York, Chicago and St. Louis delivery. Because of their reciprocal switching arrangements the Pennsylvania, the Baltimore and Ohio, the Erie, or the Wheeling and Lake Erie may be substituted for the New York, Chicago and St. Louis.

Representative routings are as follows:

P&M origin: D&H:Erie:NYC&ST.L or
NH:Erie:NYC&ST.L or
WS:NYC&St.L or
NYC:NYC&St.L or
D&H:PRR or
D&H: Erie or
NH: Erie

NH origin: PRR or B&A:NYC:
NYC&ST.L

B&A origin: NYC:NYC&St.L

There are no differential routings which apply at Cleveland. The standard all-rail routing requires approximately three days for shipments from Massachusetts.

The Terminal Company does not assess a charge for unloading either at the team tracks or the market district. Since the terminal is not a sales shed, each unit holder is obliged to truck produce consigned to him to his store for sale. On consigned cars, commission men charge shippers from $15 to $20 for unloading and trucking the shipment. Insofar as this charge is not fixed, it might be possible for shippers to make more advantageous agreements with the consignee.

Detroit

The city of Detroit is well equipped with facilities for handling and distributing produce. It has two modern terminals, owned by railroad companies, through which practically all shipped-in fruits or vegetables pass. The Detroit Union Produce Terminal was opened by the Wabash in 1929. The Michigan Central Terminal is older but has expanded its facilities to meet the needs of the trade. The plants are about on a parity although the Detroit Union Produce Terminal is the only one having auction facilities.

Each terminal is served by specific carriers. Traffic consigned to the Detroit

Union moves over the Union Belt Railroad which is owned and operated by the Wabash, Pere Marquette and the Pennsylvania.

Shipments moving to the Michigan Central Terminal are carried exclusively by the Michigan Central Railroad, a subsidiary of the New York Central.

Reciprocal switching arrangements (except between the New York Central and Pennsylvania) exist among the carriers insofar as deliveries to private sidings are concerned. No switching arrangements apply among carriers for delivery to the produce terminals.

Handling charges are in effect only at the Detroit Union Terminal. A fee of $11 per car is charged for unloading.

The shortest standard all-rail routings to the Detroit Union Produce Terminal on shipments which originate on the Boston and Maine apply for Pennsylvania delivery. A car may move either

B&M origin: D&H:PRR or
NH: PRR or
NYC:Wab. or PM

On cars that originate Boston and Maine and which are consigned to the Michigan Central Produce Terminal a routing that gives either Michigan Central or New York Central delivery may be equally direct. Among the routes over which the shipment might move are:

B&M origin: NYC:MCRR or
NYC (E):NYC (W)

Routings for cars originating on the New Haven and consigned to the Detroit Union Produce Terminal are as follows:

NH origin: PRR or B&A:NYC:Wab. or PM

The time in transit from most points in Massachusetts to Detroit is three days. On differential routings the time is supposed to be twenty-four hours longer.

Summary of Market Analysis

It is possible to draw a few general conclusions about the markets. Among them is the desirability of a beginner's adhering to the established channels. It assures him of the minimum amount of difficulty in consigning his shipments. There may be little need to suggest that it is through the organized channels that the trade in general may best become acquainted with a grower's offerings.

It will be noted that in some markets the produce district is centralized; in others it is broken up. Some markets have one terminal; others two; a few of the larger have several. The terminals may be equally well equipped to serve the trade; or one may have auction, commission sales, and storage units and the other only team tracks.

Storage facilities at the markets have not been considered in detail. The prevalent current opinion is that storage near the place of production is preferable. It enables the grower to exercise a greater and more satisfactory control over his apples, particularly as to the time of sale.

The number of railroads which serve the produce terminals in a market varies. When a grower or shipper has a choice as to which railroad shall be the delivering

carrier, the principal consideration should be the relative location of the consignee. It might prove to be most satisfactory if the consignee designated the delivering carrier. Should the shipper wish to become better acquainted with the services offered by the various carriers in a terminal, he might secure the necessary information from the New England representatives of the delivering carriers. These agents are located in Boston and are very willing to assist the shipper in solving his problems.

Conclusions

Any solution which is to bring order into the marketing of apples from New England should be based on centralized distributing units. The cooperative assembling or bringing together of the crops of several growers before definitely selecting a market is already practiced in some areas. New England apple growers in their present practices of consigning to commission men or selling to country buyers acknowledge the necessity of centralizing a supply. They realize that their crops are probably more satisfactorily merchandised if handled together than if handled individually. Some growers are of the opinion, however, that the person who acts as selling agent is not necessarily best qualified to assemble their supplies. Nor is he always able to act in the best interests of all his patrons.

In addition to personal considerations, there is the physical factor. Growers, market men, and market officials deplore the uncertainties and irregularities which are attendant upon assembling in a hit-or-miss fashion the apples of various growers. Market men have little idea what volume to expect each succeeding day. Growers are at loss to know how much should be consigned. Some assembling will always have to be performed by market men in order to supply the varying demands of their trade. For the most part, however, the function of assembling should be performed by the growers themselves.

The associations may be of two general types: (1) Packing and shipping; (2) shipping.

Either type would fulfill the present need. It would be desirable for the organization to be located near a cold storage warehouse. Such an organization and location would simplify the problem of regulating the volume moving into the market. The success, however, of a shipping unit would not be prevented even if it were not centered on a storage plant.

In addition to introducing orderliness, associations would help fulfill other needs. Growers collectively could meet the buyers' demands as to volume, grade and size specifications. They would be placed on a more nearly competitive bargaining basis with commission men, buyers or other agents. This would help remove the complaint among growers that selling or buying agents are in too advantageous a position.

For some years many growers have thought it desirable to combine their crops in order to merchandise them effectively. The low prices and large crops during the last two years have practically forced all growers to recognize the need of working out a common solution. Whereas cooperative marketing may once have been considered desirable it is now becoming necessary.

Appendix

Glossary

Bunker charge—a charge for icing.

Diversion—a change in routing instructions.

Floatage—a carload lighterage movement usually between railroad terminals.

Freight charge—the price paid for transporting the consignment from the shipping point to the destination (rail).

Freight rate—the price per unit for service; quoted by railroads usually in cents per hundredweight.

Lighterage—a terminal movement by water to complete a rail shipment.

Off-line agent—a railroad representative who has his office in a city not directly served by his company.

Reconsignment—a change in consignee.

Routing guide—a tariff listing the combinations of carriers over which a shipment may move under protection of the quoted rates.

Tariff—a published schedule of the current charges, rules, regulations, etc., in effect by railroads.

Railroad Name Abbreviations

B&A	Boston and Albany
B&M	Boston and Maine
B&O	Baltimore and Ohio
CCC&St.L	Cleveland, Chicago, Cincinnati and St. Louis
CRRNJ	Central Railroad of New Jersey
CSD	A combination of roads through Pennsylvania
CV	Central Vermont
D&H	Delaware and Hudson
DL&W	Delaware, Lackawanna and Western
Erie	Erie Railroad
MC	Michigan Central
NH	New York, New Haven and Hartford
NYC	New York Central
NYC&St.L	(Nickel Plate (New York, Chicago and St. Louis
PM	Pere Marquette
PRR	Pennsylvania
Wab.	Wabash
WS	West Shore

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE.
5M-10-'33 No. 9549

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 300 OCTOBER, 1933

Chemical Composition of Herbage from Massachusetts Pastures

By J. G. Archibald and E. Bennett

There is some evidence that nutritional disorders in livestock may be traceable to inadequacies in the natural source of feed. This investigation was undertaken in an attempt to determine the degree of variation in the composition of the herbage of natural pastures as influenced by differences in the composition and physical character of the soil.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

CHEMICAL COMPOSITION OF HERBAGE FROM MASSACHUSETTS PASTURES

By J. G. Archibald, Assistant Research Professor, and E. Bennett, Research Assistant, in Chemistry

Introduction

In connection with a series of studies on the composition of grasses it was considered advisable to make a survey of pasture conditions throughout the state.

The senior author has observed for years that young cattle often return from pasture in the autumn in poor condition: not only thin, but stunted in appearance and with harsh coats. Farmers usually dismiss this by saying that the feed has been "short", but that no permanent harm has been done to the animals; that by the time they are full grown they will be as good individuals as they would have been if their growth had not been subject to these seasonal checks.

This situation has been a matter for speculation on two counts,

(1) Is the poor condition of the stock due necessarily to scanty grazing? May it not be due in some cases to a deficiency of certain elements essential to the well-being of the animals?

(2) Do the animals make as good individuals at maturity as they would have if they had always had access to grazing unrestricted in any sense of the term? May not some of the productive and reproductive failures of mature cows be traceable to these nutritional "low spots" of their youth?

With these considerations in mind it was decided to ascertain whether there are any deficiencies in the composition of the natural herbage of our pastures, and what differences may exist between different localities in this respect.

Methods

The survey was conducted during the seasons of 1930 and 1932 in collaboration with the Department of Agronomy of the Massachusetts State College and the county agricultural agents of the four western counties of the state.[1] Approximately a hundred samples of herbage were taken from representative pastures in Worcester, Franklin, Hampshire, Hampden, and Berkshire Counties. From a majority of the pastures, samples of the surface soil were also taken. So far as possible pastures were chosen which were located on the dominant soil type of the particular region. Care was used to take samples only from areas which, according to the best information available, had never been top-dressed at all or at least not for many years.

The constituents determined were: crude protein, crude fiber, calcium, and phosphorus.[2] The relative amounts of these substances present serve as a

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[1] Grateful acknowledgment is made of the services of Dr. M. H. Cubbon, who identified the various soil types in the field, and of Messrs. J. H. Putnam, A. S. Leland, W. T. Locke, and H. J. Talmage, county agents in Franklin, Hampshire, Hampden, and Berkshire Counties, respectively, who accompanied the writer in his tour of their respective counties and aided materially in locating typical pasture areas and in securing samples of herbage. The courtesy of Dr. A. B. Beaumont and Professor R. W. Donaldson in permitting the taking of samples from areas in Worcester County located earlier by them in connection with other studies is greatly appreciated, as is also the interest and cooperation of the farmers from whose farms the samples of grass were taken.

[2] Methods used for the determination of protein and fiber were those of the Association of Official Agricultural Chemists. Calcium was determined volumetrically by McCrudden's method and phosphorus colorimetrically by the method of Fiske and Subbarrow.

fair measure of nutritive value in grass; the first two mentioned, from the standpoint of organic nutrients, the last two from the standpoint of mineral nutrients. Detailed results are shown in the appendix.

The dominant grasses in these pastures were Kentucky bluegrass (*Poa pratensis*), red top (*Agrostis alba*), and sweet vernal grass (*Anthoxanthum odoratum*). Prevalent weeds were bluets (*Houstonia coerulea*), cinquefoil (*Potentilla spp.*), dandelions (*Taraxacum spp.*), buttercups (*Ranunculus spp.*), everlasting (*Antennaria plantaginifolia*), Canada thistle (*Carduus arvensis*), yarrow (*Achillea millefolium*), sorrel (*Rumex acetosa*), and wild aster (*Aster spp.*) Moss was present in most cases, and such shrubs as hardhack (*Spiraea tomentosa*), sweet fern (*Comptonia asplenifolia*), blueberry (*Vaccinium spp.*), and brushy cinquefoil (*Potentilla spp.*) were abundant.

Interpretation and Discussion

A comparison of the average of these samples with values given by several other investigators shows that they measured up quite well so far as protein and minimum fiber content were concerned. They were fairly well supplied with calcium, some samples being quite high in that element, but for the most part they were low in phosphorus. In general, moisture, protein and phosphorus were higher in the spring, while crude fiber and calcium were higher in the autumn.

In comparing the samples from different soil types a few words of explanation as to the location and nature of the several types seems necessary.

The Gloucester series of soils is the dominant type in Worcester County and in the highlands east of the Connecticut River. The pasture soils of this series are for the most part stony fine sandy loam, glacial in origin, and usually well drained. In some places the drainage is excessive, and the series in general has a rather low moisture-holding capacity, so that pastures are susceptible to drought.

The Becket series is characteristic of the eastern highlands of Berkshire County, occurring mostly on the flattened ridges which are remnants of an old plateau. The soils are derived from glacial drift, and the texture is for the most part that of a loam. The moisture-holding capacity is good, due to the compactness of the substratum.

The Stockbridge series occurs in the western part of Berkshire County in the foothills of the Taconic mountains and is one of the most extensive and important in the county. The type is usually a heavy loam, derived from the weathering of limestone and slate. According to Latimer, crops on these soils "rarely suffer either from drought or excessive moisture."

The Colrain series of soils is confined almost entirely in this state to the foothills region of Franklin County west of the Connecticut River, largely in the towns of Colrain, Shelburne, and Conway, and extending northward into eastern Vermont. The typical soil is a fine sandy loam which has been considerably influenced by the weathering of limestone bowlders. The subsoils lack compactness and crops suffer in a dry season.

The miscellaneous types represented include two samples each from Berkshire stony loam, Blandford loam, Brookfield loam, Hinckley gravelly loam, and Worthington loam, and one sample each from Peru loam and Woodbridge stony loam. With the exception of the two samples from Brookfield loam and one from Hinckley gravelly loam, all the miscellaneous samples came from the western highlands of Hampshire County.

TABLE 1 — SUMMARY OF ANALYSES OF MASSACHUSETTS PASTURE HERBAGE

	Number of samples	Average composition—Per cent				
		Moisture	Dry matter basis			
			Protein	Fiber	Calcium	Phosphorus
Average - all samples	96	54.74	15.31	21.05	.57	.19
Average - spring samples	48	59.96	16.69	20.56	.48	.20
- autumn samples	48	49.51	14.00	21.54	.66	.19
Average - Gloucester series:						
spring samples	18	61.81	16.06	20.83	.47	.21
autumn samples	18	48.97	13.50	21.54	.59	.20
- Becket series:						
spring samples	6	52.13	18.94	19.17	.49	.18
autumn samples	6	55.91	18.06	20.56	.65	.20
- Stockbridge series:						
spring samples	6	68.11	18.13	19.44	.69	.20
autumn samples	6	55.73	15.25	20.11	.87	.21
- Colrain series:						
spring samples	6	55.67	14.44	23.16	.40	.18
autumn samples	6	41.74	10.50	23.91	.72	.14
- Miscellaneous types:						
spring samples	12	59.19	16.94	20.11	.42	.20
autumn samples	12	47.90	13.81	21.58	.62	.18
For Comparison:						
Vermont[1] (natural pasture)		.....	19.05	17.87	.85	.27
England[2] (cultivated pasture)		.....	17.65	23.00	.71	.32
Scotland[3] ((natural pasture)		.....	15.63	24.50	.46	.29
(poor hill pasture)		.....	15.88	25.20	.40	.26
West Australia[4] (good)		.....	13.03	27.80	1.18	.22
(poor)		.....	7.22	30.73	1.00	.14
New Zealand[5] (good)		.....	not reported		.59	.46
(poor)		.....	not reported		.32	.33
South Africa[6] (very poor)		.....	not reported		.42	.04

[1]Ellenberger, H. B., Newlander, J. A., and Jones, C. H. Vermont Agr. Exp. Sta. Bul. 295. 1929.
[2]Godden, W. Jour. Agr. Sci. vol. 16, Pt. 1, p. 81. 1926.
[3]Orr, J. B. Minerals in pastures. London, 1929.
[4]Underwood, J. E. Thesis. Univ. of Western Australia, 1929.
[5]Rigg, T., and Askew, H. O. New Zealand Jour. of Agr. vol. 38, No. 5. May, 1929.
[6]Theiler, A., et. al. Union of South Africa, 11th and 12th Reports of the Director of Veterinary Education and Research. Part II. Jan. 1927.

There are three principal points of interest in the figures for the different series.

(1) There was a considerably higher protein and lower fiber content in the samples from the Becket and Stockbridge series than in any of the others. The difference is believed to be due largely to the greater moisture-holding capacity of the Becket and Stockbridge loams, which results in a better class of pastures from the standpoint of both quantity and quality of the herbage. The superiority of these pastures was evident when the samples were taken, and the analyses confirm it.

(2) The calcium content of the herbage from pastures on the Stockbridge series was relatively high. This is natural, in view of the limestone origin of this soil type.

(3) There was a low average phosphorus content in the herbage from all series, falling below all but two of even the poorer values reported from other parts of the world, which have been included in Table 1 for purposes of comparison. A few scattered samples had a phosphorus content above .25 per cent, but the majority of the samples were under .2 per cent.

Orr[3] in his review of the subject points out that a good pasture will contain approximately .7 per cent of lime and .3 per cent of phosphorus. Review of the available data indicates that about .15 per cent of phosphorus in the herbage is the lower limit of safety. Below that point the deficiency may seriously limit the value of the pasture for grazing purposes, while below .1 per cent mineral deficiency diseases become prevalent.

It would seem, therefore, that many of these Massachusetts pastures are bordering on a deficiency of phosphorus, if not actually over the danger line. This statement is particularly applicable to the lighter soils toward the end of the grazing season, especially if there has been a period of drought. Note especially in this connection the September values for the samples from Colrain fine sandy loam and for most of the samples taken in Hampshire County.

One direct result of drought is to lower the moisture content of pasture grasses. In these samples correlation of this lowered moisture content with a lowered phosphorus content was very evident. The average moisture content of samples containing less than .2 per cent of phosphorus was 51.2 per cent, while for those containing .2 per cent or more of that element the average moisture content was 60.8 per cent. This correlation bears out the observation of Orr that "the percentage of phosphorus tends to decrease with drought." A similar correlation was noted between moisture content and protein content. Samples below 15 per cent of protein averaged 46.9 per cent of moisture; those over 15 per cent of protein averaged 61.1 per cent of moisture.

Results of Partial Analyses of Some of the Pasture Soils

Mention has been made of the fact that samples of the surface soil were taken from a majority of the pastures visited. Twenty of these samples have been utilized to ascertain possible differences in the acidity of the various soil types, and also to see if there was any correlation between the content of available phosphorus in the soil and the phosphorus content of the herbage.[4]

The data indicate that these soils contained in almost all cases a good proportion of fine material and were only moderately acid. The Stockbridge soils showed the influence of their limestone origin in a somewhat higher pH (closer to neutrality) than any of the others. With certain exceptions to be noted, there was little or no correlation between the available phosphorus in the soil and the phosphorus content of the grass growing on it. The exceptions are the afore-mentioned Stockbridge series of soils and certain scattered samples with high values, viz.: a Gloucester loam from Brimfield, a Becket loam from Sandisfield, and a Peru loam from Chester.

The values for the Stockbridge series are reasonably constant and also relatively high, due possibly to the influence of lime in fixing the phosphorus in relatively

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[3]Orr, J. B., Loc. cit.

[4]The hydrogen ion concentration of the soils was determined by means of a Leeds and Northrup potentiometer, using a quinhydrone electrode. Available phosphorus was determined by the method of Truog. (Jour. Amer. Soc. Agron. 22:874, 1930.)

available form. The scattered high values from other types are doubtless purely accidental. They probably represent areas which, unknown to their present owners, were formerly under cultivation and hence received applications of either manure or fertilizers. The soil which showed a very high value for available phosphorus (172 parts per million) was from a pasture which casual inspection showed to be much superior to the average from the standpoint of freedom from brush and weeds, and also with respect to the quantity of herbage and closeness of the turf.

TABLE 2 — ANALYTICAL DATA OF PASTURE SOILS

Soil type and location	Content of pasture soils			Phosphorus in pasture grass[2] (Per cent)	Ratio of phosphorus in soil : phosphorus in grass
	Fine soil[1] (Per cent)	Hydrogen ion concentration (pH)	Available phosphorus (Parts per million)		
Gloucester Loam:					
Sterling	(3)	6.09	None	0.16	.....
Webster	(3)	5.95	12.6	.21	1:167
Douglas	(3)	5.31	3.6	.23	1:639
Brimfield	51.6	5.52	46.0	.30	1:65
Hampden	53.6	5.46	8.2	.22	1:268
Prescott	61.7	5.54	2.8	.23	1:821
New Salem	57.2	5.74	6.2	.19	1:307
Average	56.0	5.66	.....	.....	.....
Colrain Loam:					
Conway	51.6	5.42	4.5	.20	1:444
Ashfield	58.6	5.63	15.0	.16	1:107
Colrain	51.5	5.63	5.6	.15	1:268
Average	53.9	5.56	.....	...	.....
Becket Loam:					
Windsor	60.6	5.13	4.8	.15	1:313
Washington	56.0	5.19	1.6	.16	1:1000
Sandisfield	66.5	5.61	24.8	.22	1:89
Average	61.0	5.31	.....	....	.....
Stockbridge Loam:					
Hancock	33.2[4]	5.32[4]	13.4	.17	1:127
Pittsfield	51.3	6.03	15.6	.24	1:154
Egremont	53.1	5.93	16.2	.15	1:93
Average	52.2	5.98	15.1	.....	1:125
Miscellaneous Types:					
Brookfield loam (Brimfield)	51.9	5.56	3.6	.22	1:611
Hinckley gravelly loam (Wales)	60.8	5.39	2.0	.22	1:1100
Woodbridge stony loam (Huntington)	67.0	5.55	2.4	.16	1:667
Peru loam (Chester)	57.5	5.85	172.0	.26	1:15

[1]The term "fine soil" is used to designate that portion of the original sample which passed through a sieve having 100 meshes to the linear inch.

[2]The values reported in this column are for the spring samples of grass taken at the time the soil samples were taken.

[3]Original unsifted sample not available for these three soils which had been sampled in 1929 by the Agronomy Department of the State College.

[4]Not included in the average. This soil contained a large amount of small, unweathered slate fragments and seemed to be of a somewhat different type from the other samples of Stockbridge loam. It is mapped, however, as belonging to the Stockbridge series.

In view of what has been said above regarding lack of correlation between available phosphorus in the soil and the phosphorus content of the grass growing on it, the wisdom of applying phosphate fertilizers to the soil for the purpose of increasing the phosphorus in the herbage, may be questioned. In fact, it is doubtful if economic considerations would warrant such a procedure.

In those cases where the evidence points to a definite shortage of phosphorus, probably a better plan would be to allow the animals access to a mineral supplement such as steamed bone meal, or to feed them small amounts daily of such concentrates as wheat bran, linseed meal, or cottonseed meal, all of which are relatively rich in phosphorus.

There is an opportunity here for further investigation in order to ascertain the efficacy of such practices under conditions in this state and in New England generally. Similar procedures in other regions of the United States and in certain foreign countries where the shortage of phosphorus is acute have proved highly beneficial.

Summary and Conclusions

A survey of Massachusetts pastures from the standpoint of chemical composition was conducted during the seasons of 1930 and 1932. Approximately one hundred samples of herbage from representative natural upland pastures were collected from various localities in the five western counties of the state. These were analyzed for moisture, crude protein, crude fiber, calcium, and phosphorus. Samples of the surface soil from some of the pastures were also tested for acidity and available phosphorus content.

In general, the herbage from pastures located on Becket loam and Stockbridge loam, two common soil types in Berkshire County, was superior to that from pastures in the counties farther east. It contained more protein and minerals and less fiber, and the quantity of grazing available was usually greater.

Judged by results obtained elsewhere and by standards formulated as a result of experience in the important grazing areas of the world, all of the samples measured up quite well in their protein content and were not unduly high in fiber. The amount of calcium ranged from fair to good, but there was quite a decided deficiency of phosphorus. This was especially true on the lighter, less drought-resistant soils and in the autumn samples.

In general, moisture, protein, and phosphorus decreased from spring to autumn, while fiber and calcium increased. There was a very definite relation between moisture content of the grass and its content of protein and phosphorus.

The soils studied were only moderately acid, having a pH range of 5.1 to 6.0, most of them above 5.5. For the most part, however, they were low in available phosphorus, which checks with the deficiency of the herbage in this respect, although no definite correlation between the two could be established.

It is concluded as a result of the study that:

(a) The moisture supply is the most important single factor in pasture management. In a region such as this, where the rainfall is quite uniformly distributed over the territory in question, the supply is dependent very largely on soil type.

(b) Poor quality of herbage is usually linked with scanty grazing.

(c) There is an opportunity for investigation of the relative seriousness of phosphorus deficiency in our natural pastures and the best means of overcoming it.

PUBLICATION OF THIS DOCUMENT APPROVED BY THE COMMISSION ON ADMINISTRATION AND FINANCE
4M-11 '33. No. 9650.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 301 NOVEMBER, 1933

Characteristics of Non-Broody and Intense Broody Lines of Rhode Island Reds

By F. A. Hays

The practical poultryman is interested in decreasing broodiness in his laying flock. The data presented here show to what extent this can be accomplished by ordinary selection methods without the use of tested males. There is included also a comparision of fecundity characters and of egg records of non-broody and broody lines.

MASSACHUSETTS STATE COLLEGE
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CHARACTERISTICS OF NON-BROODY AND INTENSE BROODY LINES OF RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

American breeds of poultry such as the Plymouth Rock, Rhode Island Red and Wyandotte normally exhibit a considerable degree of broodiness. Within recent years, however, the development of flocks for high fecundity has greatly reduced the amount of broodiness in these birds so that some flocks compare very favorably with Leghorns in freedom from broodiness. For example, the Massachusetts Agricultural Experiment Station flock of Rhode Island Reds has been reduced from 90 per cent broody in 1913 to about 14 per cent broody in the pullet year at the present time. A similar change has taken place in many flocks of the American breeds throughout the world.

The lowering of egg production by loss of time during broody periods is widely recognized. Goodale, Sanborn and White (1920) showed very definitely that Rhode Island Red females lose from 11 to 66 days in non-productive broody periods during the pullet laying year. Hays and Sanborn (1927) pointed out a net correlation of .5630$\pm$ .0097 between total days broody and annual production during the pullet year. Jull (1932, p. 228) states that 494 Rhode Island Reds at the U.S. Animal Husbandry Experiment Farm that were non-broody in the pullet year averaged 204.78 eggs compared with 477 that showed broodiness and averaged 179.65 eggs.

This report concerns itself with two lines of Rhode Island Reds bred for non-broodiness and intense broodiness, respectively, for the nine-year period of 1923 to 1931. Care was taken to avoid close matings so that with few exceptions matings no closer than cousins were made. It was necessary to introduce males and females occasionally from the production-bred flock in order to avoid close matings. Mating pens in the two lines were generally made up in part of tested hens and cocks and in part of untested pullets and cockerels. Breeding stock was selected in both lines for similarity in all traits affecting fecundity, except broodiness. The non-broody line was selected constantly for freedom from broodiness and the broody line for intense broodiness. All female breeders in the non-broody line were free of broodiness in their pullet year and all dams in the broody line exhibited broodiness the first year.

EXPERIMENTAL RESULTS

The most important inherited characters affecting egg production are age at sexual maturity, winter pause, intensity, broodiness and persistency. These five, according to Hays and Sanborn (1927, loc. cit.), are responsible for about 75 per cent of the variation in annual production in Rhode Island Reds.

1. Age at First Egg

Data on 1207 broody Rhode Island Red pullets hatched from 1916 to 1925 at this Station show that the regression of total days broody during the first laying year on age at first egg was not strictly linear. The correlation ratio was found to be .1552.$\pm$0189 and positive in nature. The magnitude of this constant is too small to indicate any significant association between age at sexual maturity and total days broody.

Table 1 gives the percentage of broody daughters in the two lines each year together with the means for the experimental period.

In general the non-broody line showed a greater absolute decrease in mean age

at first egg throughout the period than did the broody line. The differences in mean age at sexual maturity for the two lines are not significant, however, according to Fisher's (1930, p. 106) method for measuring the differences in means.

The coefficient of variation decreased slightly in both lines as the experiment progressed. For the entire period the variation amounted to 12.3 per cent in the non-broody line and 11.12 per cent in the broody line. These are insignificant differences and the variability in both lines was probably due largely to environmental factors as Hays (1932) points out.

TABLE 1. MEAN AGE AT FIRST EGG IN NON-BROODY AND BROODY LINES.

Year	Non-Broody Line				Broody Line			
	Number of Birds	Mean Age at First Egg (Days)	P.E. of Mean	Coefficient of Variability	Number of Birds	Mean Age at First Egg (Days)	P.E. of Mean	Coefficient of Variability
1923	14	220.93	6.27	.1574	27	209.41	4.32	.1594
1924	5	215.00	3.82	.0590	21	205.48	3.79	.1255
1925	60	184.35	1.32	.0823	29	195.07	1.93	.0787
1926	12	182.33	4.23	.1199	26	202.96	2.35	.0871
1927	26	173.31	1.90	.0828	38	189.63	2.36	.1141
1928	40	205.98	1.90	.0870	34	201.50	2.13	.0913
1929	33	203.27	2.41	.1012	32	202.72	2.42	.1002
1930	33	179.45	2.94	.1394	24	204.83	2.85	.1011
1931	44	188.55	1.81	.0941	28	209.89	2.17	.0808
Total or Mean	267	191.34	.97	.1230	259	201.70	.94	.1112

2. Winter Clutch Size

Mean winter clutch size has been shown to be an inherited trait and is a satisfactory measure of intensity. Intensity has also been shown to be one of the most variable characters in the flock studied (Hays, 1932, loc. cit.). Goodale et al. (1920, loc. cit.) reported lower initial egg production in a flock of broody birds where the degree of broodiness was low (1.90 periods) than in a flock of broody birds with a high degree of broodiness (5.39 periods). In the Massachusetts Agricultural Experiment Station flock from 1916 to 1925, a total of 1188 birds showing broodiness had a mean winter clutch size of 2.96 while 2679 individuals not showing broodiness in their pullet year had a mean winter clutch size of 2.50. These facts indicate an association between broodiness and winter intensity. The correlation between degree of broodiness and winter intensity amounts to $+.2548 \pm .0186$ according to Hays and Sanborn (1932 a).

Table 2 presents the mean winter clutch size by years in the non-broody and broody lines, together with their coefficients of variation and the grand means of the two lines.

There was a significant increase in intensity in both lines throughout the period. There was not, however, a change of any consequence in the variability as measured by the coefficient of variation. The high variability in winter clutch size may probably be due largely to its complex mode of inheritance, as the writer has pointed out elsewhere.

Contrary to earlier observations, mean clutch size was slightly greater in the non-broody line. The flocks hatched in 1924 and 1925 were the only exceptions. The differences in clutch size for the two lines were checked by Fisher's method, and it was found that the two lines are not significantly different in intensity.

The fact that the two lines showed about the same clutch size throughout the

nine-year period indicates that the linkage between broody genes and high intensity genes is sufficiently weak to allow much crossing over, so that non-broody birds with high intensity occur frequently and were selected as breeders in this experiment. Such a condition exists abundantly in Leghorns which may have had a similar evolutionary history.

TABLE 2. MEAN WINTER CLUTCH SIZE IN NON-BROODY AND BROODY LINES.

Year	Non-Broody Line				Broody Line			
	Number of Birds	Mean Clutch Size (Eggs)	P. E. of Mean	Coefficient of Variability	Number of Birds	Mean Clutch Size (Eggs)	P. E. of Mean	Coefficient of Variability
1923	14	2.71	.25	.5426	27	2.44	.12	.3822
1924	5	2.86	.41	.4448	21	2.90	.11	.2460
1925	60	3.29	.16	.5490	29	3.67	.22	.4670
1926	12	3.63	.21	.2945	26	3.39	.14	.3176
1927	26	4.37	.29	.4889	38	3.24	.16	.4490
1928	40	3.40	.14	.3775	34	3.28	.14	.3487
1929	33	2.79	.13	.3992	32	2.77	.12	.3779
1930	33	4.44	.20	.3801	24	4.19	.22	.3883
1931	44	4.36	.19	.4134	28	3.56	.26	.5689
Total or Mean	267	3.64	.07	.4946	259	3.26	.06	.4436

3. Winter Pause Duration

Winter pause represents a period of non-production between November first and March first of the pullet year. Hays and Sanborn (1927, loc. cit.) have shown the net correlation between total days broody and winter pause duration to be $-.1609 \pm .0245$, which indicates a slight tendency for high intensity of broodiness to be associated with short winter pause.

Table 3 presents the mean winter pause length by years for all birds in the two lines. In general the non-broody line appears to exhibit a shorter pause than the broody line. Tested by Fisher's method the two series of means differ significantly.

TABLE 3. MEAN WINTER PAUSE DURATION IN NON-BROODY AND BROODY LINES.

Year	Non-Broody Line				Broody Line			
	Number of Birds	Mean Pause (Days)	P. E. of Mean	Coefficient of Variability	Number of Birds	Mean Pause (Days)	P. E. of Mean	Coefficient of Variability
1923	14	11.00	2.53	1.7432	27	30.37	3.23	.8102
1924	5	8.60	3.60	1.2701	21	30.00	4.29	.9479
1925	60	30.55	1.72	.6388	29	26.62	2.91	.8442
1926	12	10.67	1.70	.7687	26	22.42	2.68	.8949
1927	26	15.88	2.24	1.0587	38	13.32	1.92	1.2939
1928	40	8.60	1.16	1.1301	34	16.59	2.24	1.1210
1929	33	19.67	2.30	.9694	32	21.44	2.52	.9752
1930	33	12.27	2.04	1.3559	24	17.83	2.92	1.1539
1931	44	11.48	1.97	1.6344	28	15.68	2.97	1.4719
Total or Mean	267	16.76	.79	1.1146	259	20.96	.96	1.0667

The proportion of pause and non-pause birds shown by the detailed data was 1 non-pause to 1.72 pause birds in the non-broody line compared with 1 non-pause to 1.91 pause birds in the broody line. There were four families in the non-broody line in which no daughters with pause occurred and only one family in the broody line that showed no pause daughters. Contrary to earlier observations, the effect of breeding for non-broodiness in this experiment has been to reduce winter pause duration.

4. Annual Persistency

Annual persistency is arbitrarily terminated with 365 days as a maximum. In those birds which stopped laying for 30 days or more after March first but before the close of their 365-day laying year, persistency was less than 365 days. High persistency is the most important of all inherited characters in relation to annual production, according to Hays and Sanborn (1927, loc. cit.). The net correlation between persistency and annual egg production in Rhode Island Reds is $+.7501 \pm .0063$. It is important, therefore, to discover possible relations between broodiness or non-broodiness and persistency of laying.

Although the non-broody line showed higher average persistency than the broody line in seven of the nine experimental years, the differences in the two lines were found to be of questionable significance when tested by Fisher's method for determining the significance of differences in a series of means. It is probable, therefore, that the two lines are essentially alike in persistency.

TABLE 4. ANNUAL PERSISTENCY IN NON-BROODY AND BROODY LINES.

	Non-Broody Line				Broody Line			
Year	Number of Birds	Mean Persistency (Days)	P. E. of Mean	Coefficient of Variability	Number of Birds	Mean Persistency (Days)	P.E. of Mean	Coefficient of Variability
1923	14	324.21	6.87	.1170	27	296.74	7.29	.1900
1924	5	333.40	7.24	.0723	21	329.86	7.58	.1578
1925	60	336.60	3.06	.1052	29	335.97	5.65	.1352
1926	12	322.75	9.50	.1518	26	328.54	5.59	.1295
1927	26	339.15	5.61	.1268	38	327.87	5.79	.1631
1928	40	332.13	4.29	.1223	34	325.65	6.93	.1856
1929	33	312.42	5.39	.1478	32	336.88	4.33	.1085
1930	33	347.79	3.14	.0779	24	291.83	6.90	.1716
1931	44	337.11	4.48	.1319	28	270.79	7.80	.2265
Total or Mean	267	333.33	1.67	.1225	259	317.07	2.32	.1759

5. Absence of Broodiness in the Pullet Year

The results of selection for freedom from broodiness in one line and for intense broodiness in another line are summarized in Table 5.

In the non-broody line the proportion of non-broody birds varied from about 60 to 92 per cent: in the broody line the proportion ranged from about 4 to 50 per cent. The detailed data show that no non-broody families were obtained in the broody line, except in 1923 when 40 per cent of the families were entirely non-broody. In the non-broody line the percentage of non-broody families ranged from 28.6 to 66.7 with a mean of about 50. The data do not show progress either in eliminating broodiness or intensifying broodiness in the nine-year period.

There are three possible reasons for failure to make progress: (1) Small numbers of birds were used; (2) breeding pens were made up in part of genetically untested pullets and cockerels; and (3) there was no phenotypical record on the males.

The first two difficulties may be easily met, but the progeny test offers the only partial solution of the third difficulty.

These data as well as other records of the Station flock indicate that broodiness is a trait which it is very difficult to eliminate completely. As pointed out elsewhere, a female should not be classed as non-broody because she does not become broody during her first or second laying year; for it is not uncommon for broodiness to manifest itself during the third laying year or even later. Trap-nesting may also tend to discourage the instinct in some individuals. In order to eliminate this character in any line of birds, it would at least be necessary to trap-nest all female breeders throughout their productive life and to select male breeders entirely on the progeny test after all daughters have completed at least two laying years. Such a breeding scheme is expensive and is of questionable economic value.

TABLE 5. BIRDS NON-BROODY IN THE PULLET YEAR.

Year	Non-Broody Line			Broody Line		
	Total Number of Birds	Non-Broody Birds		Total Number of Birds	Non-Broody Birds	
		Number	Per cent		Number	Per cent
1923	14	11	78.57	27	13	48.15
1924	5	1	20.00	21	1	4.76
1925	60	35	58.33	29	0	.....
1926	12	9	75.00	26	1	3.85
1927	26	24	92.31	38	19	50.00
1928	40	24	60.00	34	5	14.71
1929	33	30	90.91	32	10	31.25
1930	33	26	78.79	24	0	.....
1931	44	34	77.27	28	4	14 29
Total or Mean	267	194	72.66	259	53	20.46

6. Age at Onset of Broodiness

A number of workers have pointed out the fact that the broody instinct may not appear during the first laying year and yet may appear in later years with considerable intensity. Goodale et al. (1920, loc. cit.) have shown that broodiness appears earlier in the first laying year in more intensely broody lines. On the same basis it might be assumed that deferred broodiness may be associated with low degree of broodiness. Management may be a factor in deferred broodiness, as Punnett and Bailey (1920) indicate.

In Table 6 the non-broody line alone is studied. The table includes the percentage of non-broody daughters (pullet-year record) from dams free of broodiness during their first laying year only; from dams free of broodiness for two laying years but exhibiting the trait in the third or later years; and from dams never observed to be broody in three or more laying years. Such a tabulation considers the phenotypical behavior of the dams only and gives no consideration to the male ancestry. The phenotypical nature of the daughters is reported for the pullet laying year alone, which does not correctly classify a considerable proportion. The data do show, however, in a general way the relative effectiveness of breeding from females with different degrees of deferred broodiness and from apparently non-broody individuals in developing a line free of broodiness in the pullet year.

TABLE 6 — NON-BROODY DAUGHTERS (PULLET-YEAR RECORD) FROM DIFFERENT CLASSES OF DAMS.

(Non-Broody Line Only)

Year	Dams Not Broody until the Second Year				Dams Not Broody until the Third Year or Later				Dams Not Broody in Three or More Years			
	No. of Dams	Daughters Total No.	Daughters Non-Broody No.	Daughters Non-Broody Per cent	No. of Dams	Daughters Total No.	Daughters Non-Broody No.	Daughters Non-Broody Per cent	No. of Dams	Daughters Total No.	Daughters Non-Broody No.	Daughters Non-Broody Per cent
1923	0				1	5	5	100.00	1	9	6	66.67
1924	0				0				2	5	1	20.00
1925	1	13	5	38.46	5	30	17	56.67	3	17	13	76.47
1926	0				2	12	9	75.00	0			
1927	1	4	3	75.00	2	10	10	100.00	2	12	11	91.67
1928	1	7	4	57.14	2	15	6	40.00	4	18	14	77.78
1929	1	10	9	90.00	2	13	11	84.62	3	10	10	100.00
1930	1	2	1	50.00	4	15	10	66.67	3	16	15	93.75
1931	2	20	18	90.00	2	13	8	61.54	3	11	8	72.73
Total or Mean	7	56	40	71.43	20	113	76	67.26	21	103	80	77.67

In the nine-year period reported, the seven dams free of broodiness for only the first year gave daughters about 71 per cent of which were non-broody the first year. There was, however, considerable fluctuation in individual years, with a minimum of 38 per cent and a maximum of 90 per cent. The number of dams in this class is very small, but the data do appear to indicate some progress in eliminating broodiness by this method of selection. The fact should be stressed in this connection that only one dam of the seven gave an entire family of non-broody daughters. This particular hen (K 917) was kept only until February 2 of her second laying year, and up to that time she had not gone broody; consequently she may not be correctly classified.

Twenty dams were free of broodiness for two laying years but exhibited the trait in the third year. Considerable fluctuation is seen from year to year in the percentage of non-broodiness in daughters of these dams, but there was no progressive increase in non-broody daughters as the experiment continued. The detailed records show that nine of these dams gave no broody daughters and that the eleven remaining dams gave varying proportions of broody and non-broody daughters. From the standpoint of eliminating broodiness, this group of dams was greatly superior to the preceding group which was free of broodiness in the pullet year only.

Twenty-one dams were never observed to be broody in three or more laying years. This group might reasonably be assumed to lack one or both of the broody factors. This group of females, when mated to the same males that were used on the previous two classes of hens, gave a somewhat higher percentage of non-broody daughters. Thirteen of these dams gave no broody daughters, and the remaining eight gave varying proportions of broody and non-broody daughters.

By Fisher's method, the mean percentages of non-broody daughters from the three classes of dams do not show significant differences. Such a result might be anticipated because of the small numbers involved.

From the genetic standpoint, however, the data show that the ability to transmit non-broodiness increased with deferred broodiness in dams and can be significantly increased by selection of hens for breeding that have not gone broody in the first three or more laying years.

7. Degree of Broodiness Measured by Number of Broody Periods

One of the most satisfactory measures of degree or intensity of broodiness is the number of distinct broody periods during the laying year. In the studies reported here, degree of broodiness was recorded on all individuals during the pullet laying year, which begins with the first egg laid and ends 365 days later.

Table 7 gives the mean number of broody periods each year for the two lines throughout the experiment and the mean for the entire experimental period. This table includes only individuals that became broody and not the entire population.

The data in table 7 show very clearly that the degree of broodiness was higher in the broody line. Without exception, year after year, the mean number of broody periods per broody bird was smaller in the non-broody line. There was also a slight tendency for degree of broodiness to decrease in succeeding generations in the non-broody line. The broody line, however, does not exhibit a significant change in degree of broodiness.

The coefficients of variation for the two lines do not indicate a decrease in variability throughout the experiment. This fact suggests that degree of broodiness is affected by environmental influences, although at the present time there is no definite information as to just what these environmental factors may be.

The mean number of broody periods for the two lines in the nine year period was 2.63±.16 and 3.99±.11. The difference amounts to 1.36±.19 and is clearly significant. The data in table 7 as a whole show that the degree of broodiness in the non-broody line was distinctly less than in the broody line.

TABLE 7.— BROODY PERIODS FOR BROODY BIRDS

Year	Non-Broody Line				Broody Line			
	Number of Birds	Mean Number of Broody Periods	P. E. of Mean	Coefficient of Variability	Number of Birds	Mean Number of Broody Periods	P. E. of Mean	Coefficient of Variability
1923	3	2.67	.37	.3535	14	3.07	.31	.5567
1924	4	3.75	.28	.2211	20	5.25	.30	.3851
1925	25	2.80	.33	.8806	29	4.17	.25	.4878
1926	3	2.00	.32	.4083	25	5.96	.40	.5033
1927	2	1.00	.00	.0000	19	2.11	.17	.5315
1928	16	2.75	.31	.6618	29	4.03	.29	.5655
1929	3	2.33	.73	.8081	22	3.59	.37	.7206
1930	7	2.57	.54	.8278	24	3.42	.26	.5599
1931	10	2.20	.39	.8332	24	3.54	.26	.5405
Total or Mean	73	2.63	.16	.7746	206	3.99	.11	.6033

8. Degree of Broodiness in Daughters from Various Classes of Mothers

The intensity of broodiness in all daughters from mothers with varying degrees of broodiness is considered to throw light on the inheritance of degree of broodiness The broody line alone was used in these studies and the dams showed from one to eleven broody periods during their first laying year. Table 8 presents the detailed data.

The mean number of broody periods in all daughters from dams ranging in degree of broodiness from one to eleven broody periods showed a rather consistent increase as would be expected in an inherited character. The mean number of broody periods in daughters from the eleven different classes of dams when fitted to a straight line showed the difference in number of broody periods between all daughters of hens broody once and those broody eleven times to be 1.20 periods. Tested by the X^2 test for goodness of fit the straight line was found to fit the data.

The conclusion seems justified, therefore, that degree of broodiness measured by number of broody periods in the first laying year behaves very definitely as an inherited character. The mode of inheritance has not been worked out as yet.

TABLE 8. DEGREE OF BROODINESS IN DAUGHTERS FROM DIFFERENT CLASSES OF DAMS.

Dams' Broody Periods	Daughters			
	Number of Birds	Mean Number of Broody Periods	P. E. of Mean	Coefficient of Variability
1	31	2.23	.27	.9863
2	46	2.04	.18	.8775
3	31	3.55	.35	.8094
4	18	2.89	.41	.8855
5	33	4.21	.37	7456
6	18	3.72	.34	.5790
7	22	3.36	.40	.8339
8	9	3.89	.67	7613
9	10	1.10	.34	1.4345
10	21	5.57	.33	4016
11	14	3.29	.39	.6651

9. Laying House Mortality

Low mortality in the laying house is highly desirable from every standpoint. In Table 9 the percentage of females that died during their first laying year is recorded yearly in the non-broody and broody lines. The two lines do not show a significant difference in mortality. Considering the small number of birds used, the mortality rates in the two lines tended to be similar in the same year. The means of the two lines for the entire experimental period are almost identical. The data in Table 9 furnish no evidence of any relation between mortality rate in the laying house and the presence or absence of broodiness.

TABLE 9. LAYING HOUSE MORTALITY IN NON-BROODY AND BROODY LINES.

Year	Non-Broody Line			Broody Line		
	Total Number of Birds	Died in Laying House		Total Number of Birds	Died in Laying House	
		Number	Per cent		Number	Per cent
1923	21	5	23.81	40	9	22.50
1924	10	5	50.00	51	25	49.02
1925	81	18	22.22	47	12	25.53
1926	18	3	16.67	34	2	5.88
1927	42	13	30.95	71	28	39.44
1928	48	5	10.42	46	8	17.39
1929	70	24	34.29	50	10	20.00
1930	67	24	35.82	44	16	36.36
1931	60	13	21.67	43	10	23.26
Total or Mean	417	110	26.38	426	120	28.17

10. Winter Egg Production

Winter egg production includes the number of eggs laid by each individual from her first pullet egg up to March first. There is an intimate correlation $+.6214 \pm .0142$ between winter production and annual production in Rhode Island Reds (Hays, Sanborn and James, 1924). Table 10 records the mean winter egg production in the two lines throughout the experiment.

The data show that the non-broody line gave higher winter egg production throughout the experiment. By Fisher's method, the two series of nine mean winter records differ significantly. The weighted means for the nine-year period are also significantly different. In this experiment the non-broody line gave a winter egg production more than twelve eggs greater than the broody line.

TABLE 10. WINTER EGG PRODUCTION IN NON-BROODY AND BROODY LINES.

	Non-Broody Line				Broody Line			
Year	Number of Birds	Mean Winter Egg Record	P. E. of Mean	Coefficient of Variability	Number of Birds	Mean Winter Egg Record	P. E. of Mean	Coefficient of Variability
1923	14	61.00	5.22	.4869	27	52.37	2.43	.3582
1924	5	68.00	6.77	.3277	21	58.10	2.23	.2644
1925	60	73.52	2.16	.3376	29	73.90	3.05	.3348
1926	12	81.33	4.14	.2593	26	54.58	1.92	.2687
1927	26	99.04	2.65	.2015	38	83.39	2.68	.2931
1928	40	74.40	2.13	.2685	34	72.29	1.94	.2314
1929	33	68.67	3.00	.3722	32	70.41	2.68	.3175
1930	33	101.24	3.67	.3106	24	82.04	3.14	.2778
1931	44	90.91	2.29	.2481	28	65.93	2.65	.3166
Total or Mean	267	81.42	1.14	.3382	259	69.08	.97	.3372

11. Annual Egg Production

Annual egg records represent the number of eggs laid by each individual from her first pullet egg to a date 365 days later. In this experiment the two lines are considered first as made up of broody and non-broody individuals and second as entire populations. As stated earlier in this report, the attempt is being made to develop the two lines for similarity in all characters except broodiness. In section 3, however, the two lines are shown to differ in winter pause. In age at first egg, winter clutch size, and persistency the two lines do not differ significantly. Table 11 presents the condensed data.

Both lines were made up of broody and non-broody individuals in the pullet laying year. The 194 non-broody individuals in the non-broody line averaged 212.21±2.01 eggs per year for the experimental period, compared with 184.94 ±3.08 eggs for the 53 non-broody birds in the broody line. This is a significant difference and indicates that the two lines differed in their egg-laying ability aside from degree of broodiness.

Considering the broody individuals in the two lines, 73 in the non-broody line averaged 203.41±2.94 eggs compared with 177.50±1.48 for the 206 birds in the broody line. In the case of these two groups of birds, the difference in mean annual production may be attributed in large part to differences in degree of broodiness.

When all birds in the two lines are considered, the data show that the mean annual egg production of the non-broody line excelled that of the broody line in every year reported. The mean for the entire experimental period for the 267 birds in the non-broody line was 209.81±1.67 and for the 259 birds in the broody line, 179.02±1.34. The actual difference in this case was 30.79±2.14 eggs. By Fisher's method, the probability of obtaining chance differences in annual egg production as great as those reported in the nine-year period is zero. The data clearly indicate that the non-broody line was distinctly superior to the broody line from the standpoint of annual egg production.

TABLE 11. MEAN ANNUAL EGG PRODUCTION IN BROODY AND NON-BROODY LINES.

Year	Non-Broody Line						Broody Line					
	Non-Broody Birds		Broody Birds		Total Birds		Non-Broody Birds		Broody Birds		Total Birds	
	Number of Birds	Mean Annual Egg Record	Number of Birds	Mean Annual Egg Record	Number of Birds	Mean Annual Egg Record	Number of Birds	Mean Annual Egg Record	Number of Birds	Mean Annual Egg Record	Number of Birds	Mean Annual Egg Record
1923	11	219.36	3	229.67	14	221.64	13	183.46	14	165.00	27	173.89
1924	1	199.00	4	183.25	5	186.40	1	162.00	20	163.40	21	163.33
1925	35	201.69	25	199.32	60	200.70	0	.....	29	183.24	29	183.24
1926	9	204.56	3	225.00	12	209.67	1	169.00	25	164.80	26	164.96
1927	24	214.25	2	225.00	26	215.08	19	192.79	19	184.16	38	188.48
1928	24	204.75	16	213.31	40	208.17	5	190.20	29	180.76	34	182.15
1929	30	193.43	3	179.67	33	192.18	10	177.00	22	186.91	32	183.81
1930	26	235.08	7	183.86	33	224.22	0	.....	24	180.83	24	180.83
1931	34	226.06	10	208.00	44	221.96	4	175.50	24	181.63	28	180.75
Total or Mean	194	212.21	73	203.41	267	209.81	53	184.94	206	177 50	259	179.02

Summary

1. Two lines of Rhode Island Reds, bred for non-broodiness and broodiness respectively, were carried through a nine-year period to study the nature of the broody instinct and its relation to fecundity.

2. These two lines proved to be essentially identical in age at sexual maturity, winter clutch size, and annual persistency.

3. The non-broody line exhibited a shorter winter pause than the broody line, and also more families free from pause.

4. The mean percentage of non-broody daughters, for the period of the experiment, was 72.66 in the non-broody line and 20.46 in the broody line.

5. Dams free from broodiness for three or more years gave a significantly greater proportion of non-broody daughters than was obtained from dams free from broodiness for one or two years only.

6. The data indicate that broodiness cannot be entirely eliminated by the selection of aged broody-free dams. It seems probable that the breeding test for males offers the only possible solution.

7. The two lines showed a distinct difference in degree of broodiness in broody individuals as measured by the number of broody periods. The non-broody line had $2.63 \pm .16$ periods and the broody line $3.99 \pm .11$ periods in this experiment.

8. Degree of broodiness is definitely inherited, as shown by the fact that daughters showed a definite and consistent increase in degree of broodiness as the number of broody periods of the dams increased.

9. No difference in mortality in the laying houses was observed in the two lines.

10. Mean winter egg production was about twelve eggs greater per individual in the non-broody line.

11. Annual egg records were significantly higher for non-broody birds in the non-broody line than for non-broody birds in the broody line.

12. Annual egg production of broody birds in the non-broody line was greater than that of broody birds in the broody line.

13. When all birds are considered, the average annual production was 209.81 ± 1.67 eggs for the non-broody line as compared with 179.02 ± 1.34 eggs for the broody line.

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Publication of this Document Approved by the Commission on Administration and Finance.

3M-11-'33 No. 9723

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 302 NOVEMBER, 1933

Higher Aging Temperatures in the Manufacture of Ice Cream

By W. S. Mueller and J. H. Frandsen

A previous study of the influence of temperature on the behavior of gelatin in ice cream showed that an initial temperature of 68°F. greatly increased the viscosity and gel strength of an ice cream mix. The investigation, as reported in this bulletin, was continued to determine whether an aging temperature of 68° F. has a place in the manufacture of commercial ice cream.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

HIGHER AGING TEMPERATURES IN THE MANUFACTURE OF ICE CREAM

By W. S. Mueller, Assistant Research Professor, and J. H. Frandsen, Professor, Department of Dairy Industry

INTRODUCTION

It is a general practice in the ice cream industry today to cool the mix to approximately 40° F. over a surface cooler immediately after homogenization and then to age from 4 to 24 hours at this temperature. The study of the effect of aging on the properties of the mix and on the finished product has received much attention in both technical and practical ice cream investigation.

The time factor in aging has received more attention than the temperature factor because it appeared to be a more fertile field for investigation on account of the possibilities of wide time variation. On the contrary, the temperature factor in aging, or the practice of aging only at a low temperature, has remained unchallenged for a long time, in all probability for two reasons: (1) It was thought that the aging temperature was limited by bacterial growth to a narrow range, 32° to 40° F., and (2) it was thought that the desirable changes which occur during aging were favored by low temperatures and therefore the lower the temperature, the greater the benefits to be derived from aging.

A previous study by the senior author (1) showed that a short aging period at high temperature, followed by aging at a low temperature, increased the basic viscosity and gel strength of both gelatin ice cream mixture and pure gelatin water solution, when compared with a solution aged at a low temperature only. Of the various high initial aging temperatures tried, 68° F. gave the maximum increase in basic viscosity and gel strength. These results indicate that the efficiency of the gelatin was increased by a short aging period at high temperature followed by a low temperature aging period.

The purpose of the investigation reported in this bulletin was (1) to determine whether this increase in gelatin efficiency, due to initial aging at a high temperature, would be carried over to the finished product, and (2) to determine the merits and disadvantages of aging at 68° F. when compared with aging at a low temperature (38° F.).

HISTORICAL

So far as known no data have been published on the effects of aging time and temperature on the quality of ice cream when an aging temperature above 50° F. was used for definite periods of time.

DePew ([2]) made a preliminary study of the effect of rate of cooling on the viscosity of an ice cream mix. The time intervals allowed for cooling the mix from 145° to 50° F. varied from 4 minutes to 50 minutes. After cooling to 50° the mixes were aged at 40° for 24 hours. The results from four trials indicated that the rate of cooling the mix after homogenization did not materially affect its viscosity after being aged.

Wright ([3]) studied the effect of initial cooling temperatures on the behavior of gelatin in an ice cream mix and in skim milk. After homogenization the ice cream mixes were cooled rapidly to the desired initial aging temperatures and then were placed in storage (40° F.) where they cooled very slowly without agitation to approximately storage-room temperature. Under those conditions no definite conclusions could be drawn as to the effect of high initial aging temperatures for varying periods of time because the temperature was not controlled during the initial aging period. However. this work showed that the rate of cooling an ice cream mix immediately after homogenization greatly influenced the behavior of the gelatin in the mix.

PLAN OF EXPERIMENT

The general plan of this investigation was to age one portion of an ice cream mix at 68° and the other portion at 38° F. and make comparisons on the following points: bacterial growth, titratable acidity, H-ion concentration, basic viscosity, whipping ability, body and texture, melting resistance, and melting appearance.

The high temperature (68° F.) was used in two ways: (1) as an initial aging temperature for 4 hours, followed by a low temperature (38° F.) aging period of 20 hours; (2) as the only aging temperature for a period of 4 hours. However, in the latter method the mix was cooled to 38° before it was placed in the freezer. The 68° aging period remained constant at 4 hours, except for the first experiment, in which the effect on bacterial growth, pH and titratable acidity was studied. The aging periods for the control mixes (38°) were always equal to the total aging period of the mixes aged at 68°.

The influence of varying the gelatin content and the mix composition on the magnitude of the effects of aging at a high temperature was also studied.

Experimental Methods

Since the ingredients and composition of the mix varied in this study, the description of the mix is given for each experiment. The gelatin used was a mixture containing samples of approximately 175 Bloom strength which were obtained from nine gelatin manufacturers. The three sources of gelatin, namely, calf skin, pork rind. and ossein, and also the various processes for manufaturing gelatin, were represented. This composite sample tested 176 (Bloom strength) with pH 5.25.

Mixes were pasteurized at 145° F. for 30 minutes and homogenized at 2500 pounds pressure at the temperature of pasteurization. In preliminary trials small batches were pasteurized in ice cream cans set in hot water and cooled by setting the cans in cold brine. The small batches were aged at 68° in a thermostatically controlled incubator and at 38° in the cooler. The preliminary trials were checked, using batches of approximately 300 pounds which were pasteurized in a commercial pasteurizer and cooled over a surface cooler. These large batches were aged at 68°, either in the holding tank or by setting 40-quart milk cans in water, and aged at 38° in the cooler.

The preliminary mixes, one-half gallon in size, were frozen in an experimental brine freezer which is similar in mechanical construction to a commercial brine freezer. The preliminary experiments were checked by freezing in a 40-quart brine freezer. The brine temperature varied from +2° to —5° F. Freezing

data were secured by determining the temperature of the mix in the freezer and the percentage of overrun at intervals of 1 minute throughout the freezing process. All of the samples (pint cartons) within a given series used for comparison were drawn at the same temperature and at approximately 85 per cent overrun. The overrun of all samples used for judging was checked by calculations from volume and weight determinations.

Melting resistance data were secured by subjecting all samples to the same thermal conditions and noting the appearance of the sample and the rate of melting. The samples remained in the hardening room (approximately 0° F.) for several days, after which they were placed on 0.25-inch mesh wire screening over the mouth of a funnel supported by a ring stand. Room temperature varied from 70° to 75° F. The melted ice cream was weighed after the samples had been exposed for 1½ hours, and photographs were also taken at that time.

Approximately one and three weeks after being frozen the ice cream was judged by members of the college staff and a class in judging dairy products. Samples within each group used for comparison were placed numerically and a three to one preference was assumed to be significant.

The term "basic viscosity" in this investigation is defined as the viscosity which persists in an ice cream mix after being stirred by ordinary means until there is no further reduction in consistency. The samples were first tempered to 68° F. in a constant-temperature bath, then agitated by means of a motor-driven paddle consisting of a 0.25-inch mesh wire screen. The device was arranged so as to prevent the incorporation of air and so that the sample could be agitated while remaining in the constant-temperature bath. A constant agitation time of 10 minutes was used because a preliminary experiment showed no decrease in consistency of the mix after 10 to 30 minutes of agitation. Basic viscosity determinations were made with the MacMichael viscosimeter, when using the disc bob, and rotating the cup which contained 125 cc. of mix at 68°, at a speed of 15 r.p.m. Duplicate or triplicate determinations were made. The viscosity measurements were made at a fixed time (3 minutes) after the samples were agitated in order to prevent any appreciable recovery in the viscosity of the mix. All results are reported in degrees MacMichael for No. 30 gauge wire.

EXPERIMENTAL RESULTS

The Effect of Aging at 68° F. on Bacterial Growth, pH, and Titratable Acidity

Before studying the effect of aging at a high temperature on the quality of the finished product, it seemed desirable to determine its effects on bacterial growth, pH and titratable acidity as these factors are of importance in determining the practicality of using a high temperature. In order to make this study applicable to commercial conditions, mixes having different initial bacterial counts were used. These differences in initial bacterial count were secured by varying the pasteurization time and by using raw materials of varying quality. Both butter and sweet cream mixes were used in this experiment. Skim milk powder was the chief source of serum solids. The mixes were prepared and processed according to standard procedure as given under experimental methods. After homogenization, the mixes were cooled rapidly to 68° F. and then aged at this temperature in a constant temperature water bath (±0.1°). Bacterial platings and pH and titratable acidity determinations were made on the mix before aging and after

aging for 2, 4, and 6 hours at 68°. A parallel sample, but aged at 38° served as the control in each case. Bacterial counts were determined by means of the standard plate method. A Leeds and Northrup laboratory potentiometer using the quinhydrone electrode was used in making the hydrogen-ion determinations. The determinations of titratable acidity were made by the Mann's acid test, using N/10 NaOH with phenolphthalein indicator.

The results of this experiment are given in Tables 1 and 2 and are the average of duplicate determinations. The data indicate that the effect of aging a pasteurized mix for 2, 4, or 6 hours at 68° F. is of little consequence in commercial ice cream manufacture as far as bacterial count, pH and titratable acidity are concerned. The data on aging at 38° are in agreement with the findings of other investigators.

TABLE 1. EFFECT OF AGING AT 68° F. ON BACTERIAL GROWTH IN A PASTEURIZED MIX

Time and Temperature of Aging	Bacterial Count Per Gram					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Before Aging	50,000	10,500	10,300	15,300	1,170,000	4,100
Aged 2 hours:						
At 38° F.	45,000	12,500	8,500	13,800	1,179,000	.....
At 68° F.	52,000	10,000	8,300	18,700	1,220,000	.....
Aged 4 hours:						
At 38° F.	54,900	12,500	8,200	9,600	1,212,000	.....
At 68° F.	50,500	11,500	11,700	17,000	1,516,000	.....
Aged 6 hours:						
At 38° F.	42,000	10,000	8,900	10,800	1,015,000	3,700
At 68° F.	51,400	12,000	10,000	10,900	1,110,000	3,700

TABLE 2. EFFECT OF AGING AT 68°F. ON THE pH AND TITRATABLE ACIDITY OF A PASTEURIZED MIX

Time and Temperature of Aging	Trial 1		Trial 2		Trial 3		Trial 4	Trial 5
	Per cent Acidity	pH	Per cent Acidity	pH	Per cent Acidity	pH	Per cent Acidity	Percent Acidity
Before aging	0.182	6.30	0.180	6.10	0.190	5.98	0.180	0.200
Aged 2 hours:								
At 38° F.	.180	....	....	....	.190	6.00	.185	.200
At 68° F.	.182	6.30	.180	6.25	.190	5.98	.185	.190
Aged 4 hours:								
At 38° F.	.190	6.28	....	....	.190	6.00	.190	.195
At 68° F.	.182	6.33	.180	6.15	.190	5.95	.190	.190
Aged 6 hours:								
At 38° F.	.190	6.30	.180	6.30	.190	5.98	.185	.195
At 68° F.	.180	6.35	.182	6.13	.190	5.98	.185	.200

The bacteriological results are surprising because it has been taught that even a pasteurized mix must be cooled immediately after homogenization to approximately 40° F. in order to avoid increases in bacterial growth. The probable reason for no marked increase in bacterial growth even after holding the mix at 68° F. for 6 hours is the natural lag period which follows sudden temperature changes. However, such factors as sugar concentration, surface tension and types

of organism surviving pasteurization must not be overlooked. The probable reason for no marked increase in titratable acidity and H-ion concentration is that pasteurization destroys most of the lactic acid producing organisms and that the mix is highly buffered.

The Effect of Variations in Aging time and Temperatures of the Mix on Basic Viscosity, Whipping Ability and Quality of the Ice Cream

Four aging treatments were used in this experiment:—4 hours at 38° F., 4 hours at 68° F., 24 hours at 38° F., 4 hours at 68° F. plus 20 hours at 38°.

Aging for 4 hours at 68° F. was tried because of the recent recommendations of a short aging period. Since in commercial practice it is sometimes inconvenient to freeze immediately after the 4-hour aging period, this was followed by a low temperature aging period. Although both 4- and 24-hour aging periods at a low temperature (approximately 40°) have been studied extensively, they were included in this experiment to serve as controls.

A sweet cream mix testing 14 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.4 per cent gelatin (176 Bloom) was processed according to standard procedure as given under experimental methods. Immediately after homogenization the mix was divided and one portion cooled rapidly to 68° F., the remaining portion to 38°. The 38° lot was again divided, and the two portions aged for 4 and 24 hours, respectively, in the cooling room (approximately 38°). The 68° lot was aged 4 hours in a thermostatically controlled incubator, after which the mix was cooled rapidly to 38°, then one portion was immediately frozen while the remaining portion was aged for 20 hours at 38°.

Table 3. The Effect of Aging at 68° F. on Basic Viscosity, Melting Resistance, and Body and Texture

(Sweet cream mix containing 14 per cent fat, 10 per cent serum solids, 15 per cent sugar, and 0.4 per cent gelatin (176 Bloom).)

Aging Treatment	Basic Viscosity °M	Per cent Melted after 1½ Hours Exposure	Numerical Rating for Body and Texture
4 hours at 38° F. (control)	50.75	65.3	4
4 hours at 68° F.	49.50	36.1	1
24 hours at 38° F (control)	54.22	77.6	3
4 hours at 68° F. + 20 hours at 38° F.	74.77	53.0	2

Data on basic viscosity, melting resistance, and body and texture, as given in Table 3, are the average of four trials. There was not much difference in basic viscosity except in the case of the samples aged 4 hours at 68° plus 20 hours at 38°, which were noticeably higher. A comparison of the samples aged for 4 hours and 24 hours at 38° agrees with previous findings that the basic viscosity increases only slightly after 4 hours up to 24 hours aging.

The ratings for body and texture show that aging at the high temperature produced better results in both cases, with only a slight difference in favor of the short aging period. A comparison of the samples aged at 38° only, showed that the longer period produced slightly better body and texture.

The data on melting resistance are given in Table 3, and the appearance of the melting ice cream is shown in Plates 1 and 2. These results show that the samples aged at 68° F. had greater melting resistance than those aged at 38° only. This increase, however, was greatest in the mixes aged at 68° only. Aging for 4 hours at 38° gave a slightly higher melting resistance than aging for 24 hours at 38° F. The aging temperature also affected the appearance of the melting ice cream. Samples which were aged at 38° only had a normal melting appearance, while those aged at 68° F. showed a curdled appearance on melting, which was less pronounced when the 68° aging period was followed by a 38° aging period. This melting defect was more evident than is shown in Plate 1. Plate 2 is a close-up view showing more plainly the undesirable melting appearance of a high initially aged mix provided gelatin content is not changed.

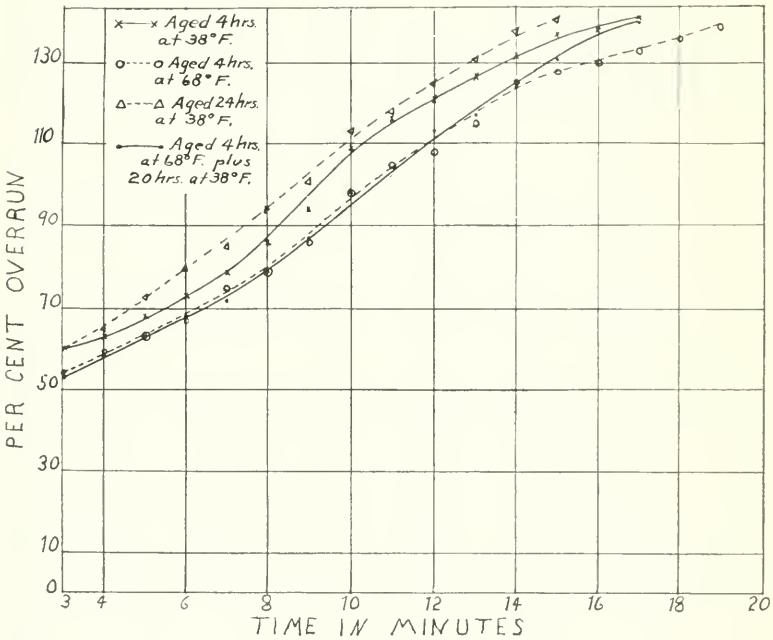

Chart 1. — The Effect of Aging at 68° F. on the Whipping Ability of Mixes Containing 0.4 per cent Gelatin.

The overrun data shown in Chart 1 are the average of two trials. From this graph we may conclude that aging at 68° F., either alone or followed by a low temperature aging period, retarded the rate of whipping when compared with aging at 38°. However, the maximum overrun obtained was the same for all mixes. The data on the rate of whipping of mixes aged at 38° for 4 and 24 hours show that the longer aging period increased the rate of whipping somewhat.

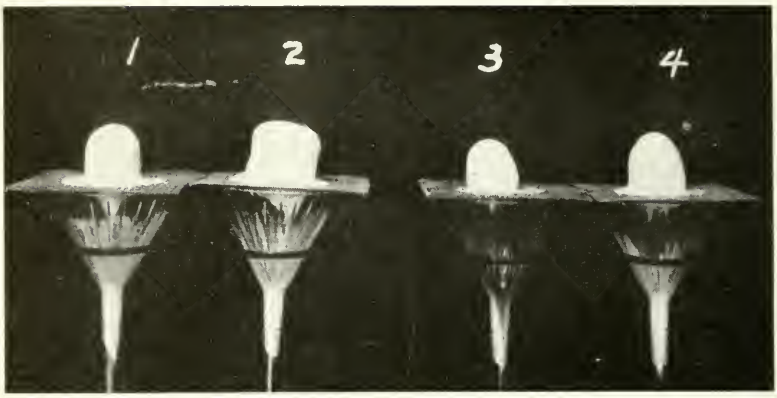

Plate 1. — The Effect of Aging at 68° F. on Melting Resistance.
(0.4 per cent Gelatin Used.)
1 — Aged 4 hours at 38° F. (control).
2 — Aged 4 hours at 68° F.
3 — Aged 24 hours at 38° F. (control).
4 — Aged 4 hours at 68° F. plus 20 hours at 38° F.

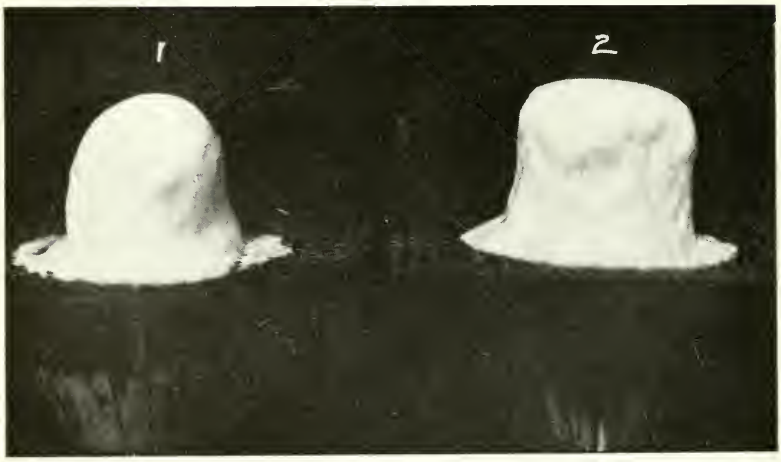

Plate 2. — The Effect of Initial Aging at 68° F. on Melting Appearance.
(0.4 per cent Gelatin Used.)
1 — Aged 24 hours at 38° F. (control).
2 — Aged 4 hours at 68° F. plus 20 hours at 38° F.

Plate 3. — The Effect of Initial Aging at 68° F. on Melting Resistance when the Gelatin Content was Decreased.
1 — 0.4 per cent Gelatin (control), aged 24 hours at 38° F.
2 — 0.3 per cent Gelatin, aged 4 hours at 68° F. plus 20 hours at 38° F.
3 — 0.2 per cent Gelatin, aged 4 hours at 68° F. plus 20 hours at 38° F.

Plate 4. — The Effect of Initial Aging at 68° F. on the Melting Resistance of a Gelatin-free Mix.
1 — Aged 24 hours at 38° F. (control).
2 — Aged 4 hours at 68° F. plus 20 hours at 38° F.

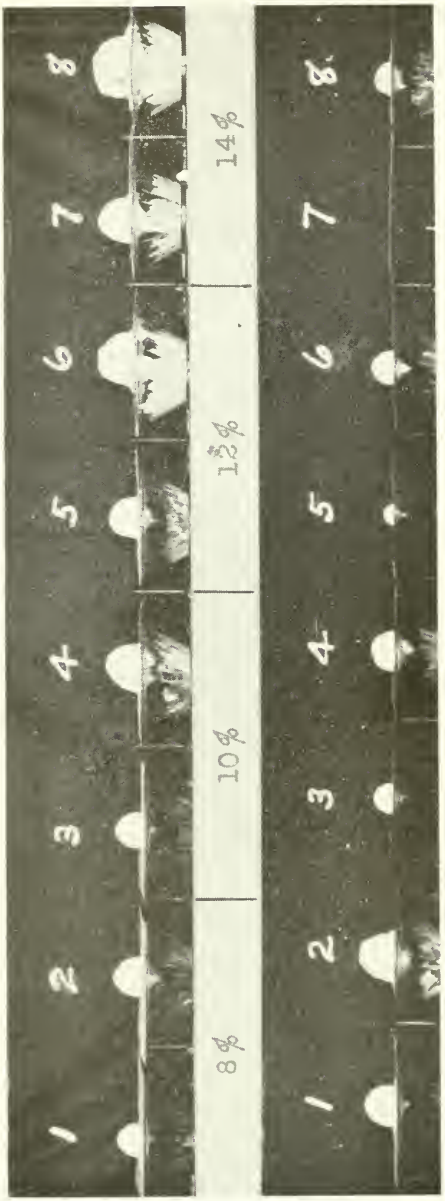

Plate 5. The Effect of Initial Aging at 68° F. on the Melting Resistance of Ice Creams Varying in Butterfat or Serum Solids Content.
Upper Series: 8, 10, 12, and 14 per cent butterfat, respectively.
Lower Series: 8, 10, 12, and 14 per cent serum solids, respectively.
Both Series: {1, 3, 5, 7—Aged 24 hours at 38° F. (controls).
{2, 4, 6, 8—Aged 4 hours at 68° F. plus 20 hours at 38° F.

The Influence of Gelatin Concentration on the Effect of Initial Aging at 68°F.

The preceding experiment showed that aging at 68° F. increased the efficiency of the gelatin. The next logical step was to determine whether or not this observed increase in gelatin efficiency was sufficient to warrant a reduction in amount of gelatin used.

Sweet cream mixes containing 14 per cent fat, 10 per cent serum solids, and 15 per cent sugar were processed according to standard procedure as given under experimental methods. The control mix contained 0.4 per cent gelatin and was aged at 38° F. for 24 hours. Mixes identical to the control, except in gelatin concentration, were aged 4 hours at 68° plus 20 hours at 38°. The variables in gelatin concentration were 0.2 per cent and 0.3 per cent. Since the preceding experiment showed the effect of high temperature aging with a 0.4 per cent gelatin, it was not repeated in this experiment.

TABLE 4. THE EFFECT OF INITIAL AGING AT 68° F. ON THE BASIC VISCOSITY, MELTING RESISTANCE, AND BODY AND TEXTURE, WHEN THE GELATIN CONTENT WAS DECREASED

(Sweet cream mix containing 14 per cent fat, 10 per cent serum solids, and 15 per cent sugar.)

Per cent Gelatin (176 Bloom)	Aging Treatment	Basic Viscosity °M	Per cent Melted after 1½ Hours Exposure	Numerical Rating for Body and Texture
0.4 (control)	24 hours at 38° F	51.50	63.4	Equal
0.3	4 hours at 68°F.+20 hours at 38°F.	45.67	58.8	
0.2	4 hours at 68°F.+20 hours at 38°F.	36.22	70.1	3
0	24 hours at 38°F. (control)	21.55	33.9	Equal
0	4 hours at 68°F.+20 hours at 38°F	25.35	30.5	

NOTE: The no-gelatin series should not be directly compared with the mixes containing gelatin.

The body and texture results were used as the major criteria for determining the amount of gelatin which may be displaced by using 68° F. as the initial aging temperature. The data in Table 4 show that a mix containing 0.3 per cent gelatin and initially aged at 68° F. was equivalent in body and texture to a 0.4 per cent gelatin mix aged at 38° only. The appearance of the melting ice cream is shown in Plate 3. It should be noted that samples 1 (control) and 3 have a normal melting appearance. Sample 2 has a very slight curdled appearance, which, however, is too slight to be of commercial significance. Since the 0.2 per cent gelatin sample melted normally and the 0.3 per cent sample was slightly curdled, the indication is that a gelatin content between the two might be better from the standpoint of melting behavior. The results of this experiment show that the objectionable melting behavior, which occurs when a mix containing the usual percentage of gelatin is initially aged at 68°, can be corrected by reducing the gelatin content.

The overrun data for samples 1, 2, and 3 are given in Chart 2, and showed equal whipping ability, or at least no differences which would have any commercial significance.

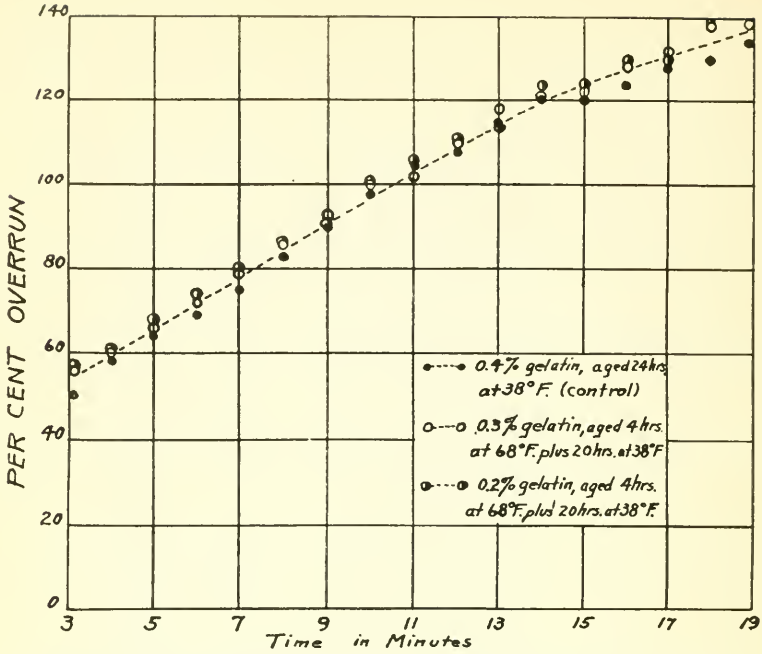

Chart 2. — The Effect of Initial Aging at 68° F. on the Whipping Ability of Mixes when the Gelatin Content Was Decreased.

Effect of an Initial Aging Period at 68° F. on a Gelatin-Free Mix

A sweet cream mix containing 14 per cent fat, 10 per cent serum solids, 15 per cent sugar and no gelatin was processed according to standard procedure as given under experimental methods. One half of the mix was aged for 24 hours at 38° F., and the remaining portion aged at 68° for 4 hours, then at 38° for 20 hours. The results (see Table 4, Chart 3, and Plate 4) show that the difference in aging temperature had no significant effect on basic viscosity, melting resistance and appearance, and whipping ability. This indicates that the effects of initial aging at 68°, which were observed in the preceding experiments, were due primarily to the gelatin and not to the milk constituents. In all probability the peculiar melting behavior of the ice cream containing no gelatin was due to the presence of foam on the melting surface which retarded the rate of melting.

The Influence of Composition of Mix on the Magnitude of High Initial Aging Temperature Effects

In order to study the effect of butterfat and serum solids on the behavior of gelatin when the mix was initially aged at 68° F., the fat and serum solids were varied from 8 to 14 per cent. A butter, skim milk powder, and water mixture was selected for the standard mix in this experiment, as it was found that the physical properties of such a mix could be more readily duplicated from day to day than

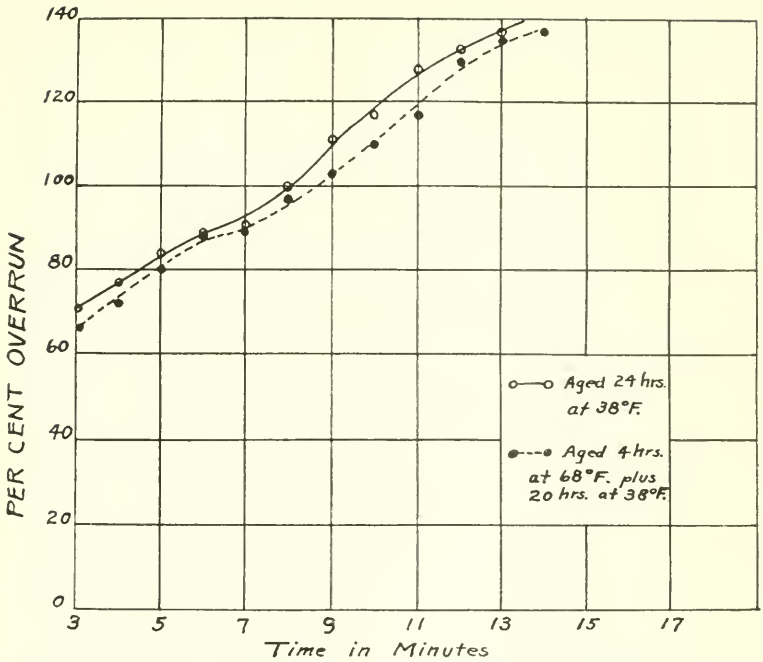

Chart 3. — The Effect of Initial Aging at 68° F. on the Whipping Ability of Gelatin-Free Mixes.

when the mix was made of cream, fresh skim milk, and skim milk powder. The mixes were prepared and processed according to standard procedure as given under experimental methods, aged for 4 hours at 68° then rapidly cooled to 38° and aged at this temperature for 20 hours. Each of these mixes was compared with a control which was aged at 38° for 24 hours. The results are reported as increases or decreases over the control.

Results Obtained when Varying the Percentage of Butterfat

The butterfat content was varied at 2 per cent intervals from 8 to 14 per cent, while the serum solids, sugar and gelatin remained constant at 10 per cent, 15 per cent, and 0.5 per cent (176 Bloom strength), respectively; thus giving a variation in total solids from 33. 5 per cent to 39.5 per cent at 2 per cent intervals. All determinations were made in duplicate and the data reported in Table 5 are the average for two trials. Increasing the percentage of butterfat from 8 to 14 per cent had the following effect on the results of aging at a high initial temperature, as compared with aging at 38° F. (See Table 5 and Plate 5.)

1. Magnified the increase in basic viscosity.
2. Magnified the increase in melting resistance.
3. Did not definitely alter the decrease in maximum overrun.

The ice creams aged at the high initial temperature were judged superior in body and texture to those aged at a low temperature only. This improvement in body and texture was magnified as the butterfat content increased.

TABLE 5. INCREASE IN BASIC VISCOSITY AND MELTING RESISTANCE, AND DECREASE IN OVERRUN OF MIXES INITIALLY AGED FOR 4 HOURS AT 68° F. OVER THOSE AGED ONLY AT 38° F.

Composition of Mix			Increase in Basic Viscosity	Increase in Melting Resistance	Decrease in Maximum Overrun
Fat	Serum Solids	Total Solids			
Per cent	*Per cent*	*Per cent*	*°M*	*Grams Melted Ice Cream*	*Per cent*
8	10	33.5	9.75	20.3	8.0
10	10	35.5	25.75	30.1	6.0
12	10	37.5	35.75	50.6	9.0
14	10	39.5	21.03	82.6	4.0
10	8	33.5	13.31	59.2	7.0
10	10	35.5	25.75	30.1	6.0
10	12	37.5	32.83	22 6	3.0
10	14	39.5	41.85	—8.9	8.0

Results Obtained when Varying the Percentage of Serum Solids

This experiment was similar to the preceding, except that in this case the fat remained constant at 10 per cent, while the serum solids were varied. Increasing the serum solids from 8 to 14 per cent, at 2 per cent intervals, had the following effect on the results of aging at a high initial temperature as compared with aging at 38° F. only. (See Table 5 and Plate 5.)

1. Magnified the increase in basic viscosity.
2. Diminished the increase in melting resistance.
3. Did not definitely alter the decrease in overrun.

The ice creams aged at the high initial temperature were again judged superior in body and texture to those aged at a low temperature only. This improvement in body and texture was also magnified as the serum solids were increased.

The increase in melting resistance, normally caused by high initial temperature, disappeared as the serum solids were increased, due in all probability to the effect of lactose.

PRACTICAL APPLICATIONS

Observations on melting appearance made in this study suggest a possible explanation for variations which sometimes occur in the melting behavior of ice cream of uniform composition. Although several causes for excessive retardation of melting and curdled appearance of melting ice cream have been explained in the literature, yet a number of ice cream manufacturers have trouble in producing a uniform product, even when a standardized formula and processing procedure are used. This fact indicates that some unknown factors are contributing to the serious defect. In one instance where the ice cream varied considerably in melting behavior, it was found that the mix was not being cooled after homogenization to a uniformly low temperature each day. In another instance, some years ago, a large ice cream plant was using a surface cooler where tap water was the only cooling medium. After a change was made to cooling with brine, the properties

of the finished ice cream were different, although the composition of the mix was the same as before. No explanation could be found at that time for the change in the finished product. In another case, more recently, mixes were being cooled over a surface cooler where tap water was the only cooling medium. The mix left the cooler at approximately 70° F. and was stored in ten-gallon cans in a cooler at 50°. Under those conditions the mix was really being initially aged at a temperature above 50° for some time. These practical illustrations show that in ice cream plants where the cooling of the mix after homogenization is not being carefully checked, mixes may be aged for several hours at a temperature above 50° F.

There are two methods by which the ice cream manufacturer may correct the excessive retardation of melting and the curdled appearance on melting, when they are due to a high initial aging temperature. (1) If he is using the optimum amount of gelatin for low temperature aging, the mix should be cooled immediately after homogenization to approximately 40° F. (2) If he wishes to initially age the mix at approximately 68° F. for two to four hours he should reduce the gelatin (176 Bloom) content approximately 25 per cent from that ordinarily used. Since the 68° F. temperature, alone or followed by a low temperature, results in an increase in gelatin efficiency, its use is quite flexible and therefore can be adapted to the needs of the manufacturer. For instance the mix may be frozen immediately after the high temperature aging period, or it may be cooled to approximately 38° F. and frozen the following day.

SUMMARY AND CONCLUSIONS

1. In an ice cream mix containing gelatin, the efficiency of the gelatin was increased by aging for 4 hours at 68° F., whether this was followed by aging at a lower temperature or not.

2. This increased gelatin efficiency was evidenced by improvement in body and texture, increase in melting resistance and slight retardation in rate of whipping when compared to an identical mix aged at 38° F.

3. When an ice cream mix containing 14 per cent fat, 10 per cent serum solids, 15 per cent sugar and 0.4 per cent gelatin (176 Bloom) was aged at 68°F. for four hours, the efficiency of the gelatin was increased to such an extent that the gelatin content could be reduced approximately one-fourth without any loss in the quality of the finished product.

4. A pasteurized ice cream mix was aged at 68° F. for 2, 4 and 6 hours without any measurable effect on bacterial growth, pH, or titratable acidity, which would be of any commercial significance.

5. An ice cream mix containing gelatin showed a slight decrease in viscosity when aged for 4 hours at 68° F. but a great increase in viscosity when this initial aging period was followed by 20 hours at 38°. In both cases the comparison was made with ice cream mixes aged for 24 hours at 38° F.

6. The effects of high temperature aging could not be directly correlated with basic viscosity values.

7. Aging at 68° F. for 4 hours had no marked effect on the consistency and whipping ability of the mix or on the melting resistance, body, and texture of the finished product, when the ice cream mix contained no gelatin or other stabilizer.

8. When an ice cream mix which contained the correct amount of gelatin for low temperature aging was aged for 4 hours at 68° F., excessive retardation in melting and a curdled appearance resulted. This objectionable melting condition can be corrected by reducing the gelatin content approximately one-fourth.

9. In ice cream plants where the cooling of mixes is not being carefully checked, mixes may be aged unintentionally for several hours at a temperature above 50° F. This undoubtedly is a big factor in causing the excessive retardation of melting and the curdled appearance on melting which have troubled some ice cream manufacturers but which previously have not been explained.

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Publication of this document Approved by Commission on Administration and Finance.
3M-1-'34. N. O. 16.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 303 DECEMBER, 1933

Effect of Hydrocyanic Acid Gas on Cucumber Plants Previously Sprayed with Copper Fungicides

By E. F. Guba and E. B. Holland

The control of fungous diseases and insect pests of cucumbers in greenhouses frequently requires the use of copper fungicides and hydrocyanic acid gas. Complete destruction of greenhouse cucumber plantings has occurred in Massachusetts in some instances from such treatment. This study was undertaken to determine the nature and the range of this incompatibility and to formulate a safe procedure.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

EFFECT OF HYDROCYANIC ACID GAS ON CUCUMBER PLANTS PREVIOUSLY SPRAYED WITH COPPER FUNGICIDES

By E. F. Guba, Assistant Research Professor of Botany, and E. B. Holland, Research Professor of Chemistry

INTRODUCTION

The extensive greenhouse area devoted to the forcing of vegetables in Massachusetts has for many years necessitated study of control measures for insect pests and fungous diseases peculiar to these crops. Such studies have encouraged the use of fungicides and insecticides, and the intermingled application of these materials presents a problem of the utmost importance to the growers. One of these problems relates to the conflict existing between copper fungicides and hydrocyanic acid gas.

The understanding and solution of this problem has necessitated consideration of copper fungicides of different reaction, concentration, and composition and of different sources of hydrocyanic acid gas. The classification of the compatibility of copper fungicides with gas on cucumber plants and confirmatory knowledge obtained from chemical analyses of the spray residues would appear to contribute to our knowledge of the problem and suggest recommendations for a safe procedure.

HISTORICAL REVIEW

It has been noted by Guba (3, 4) that Bordeaux mixture and hydrocyanic acid gas are incompatible when gas follows spray in the greenhouse, and that when Bordeaux is used to control diseases tobacco fumigants should be substituted for the gas to avoid injury. Published information suggested that the gas (HCN) combined with copper to form cupric cyanide $Cu(CN)_2$, an unstable compound giving off cyanogen and leaving insoluble cuprous cyanide, $Cu(CN)$.

Butler and Jenkins (1) have reported that as the ratio of lime to copper sulfate is increased in Bordeaux from 4-1-50 to 4-4-50 injury increases, and then decreases as the ratio is increased to 4-24-50. They claim that neutral Bordeaux, as represented by the formula 4-0.8-50, followed by gas is safe and that mixtures with high lime ratios, e.g. 4-16-50 and 4-24-50, are safe if the plants are kept dry after gas. According to these investigators, injury with certain ratios of lime to copper sulfate and none with others is correlated with the allegation that (a) insoluble cuprous cyanide is formed with a 4-0.8-50 mixture; (b) no cupric cyanide is formed with a 4-0.8-50 mixture but increasing amounts with mixtures up to 4-4-50, negligible amounts with 4-16-50 and none with 4-24-50; (c) the soluble double salt is formed in increasing amounts with 4-4-50 to 4-24-50 mixtures.

Quayle (13) was unable to confirm the safety of Bordeaux 4-0.8-50 with gas on lemon, but reported less injury than with Bordeaux 4-4-50, and that it was similarly graduated but more marked on increasing the interval between spray and gas. A spray of zinc sulfate and lime was safe, but it is not as effective as Bordeaux in controlling the brown rot disease caused by the fungus *Pythiacystis citrophthora* Sm. & Sm. It is, therefore, obvious, on the basis of our present state of knowledge of the problem, that further investigation is extremely desirable.

PRACTICAL CONSIDERATIONS INVOLVED

Copper fungicides are used to control some diseases of vegetable and ornamental crops under glass in Massachusetts. Bordeaux is frequently used to assist in the control of cucumber powdery and downy mildews, caused respectively by the fungi *Erysiphe cichoracearum* DC. and *Peronoplasmopara cubensis* (B. & C.) Clint., and no other commercial greenhouse crop in Massachusetts has been subject to greater destruction as the result of the incompatibility of Bordeaux with hydrocyanic acid gas. However, only 1-1-50 and 1-½-50 mixtures can be used since the higher concentrations cause hardening and stunting of growth. Some other minor uses for Bordeaux on greenhouse plants may be cited, but no diseases of greenhouse crops are known which require for their control such ratios of Bordeaux as 4-16-50 and 4-24-50. These mixtures are very difficult to apply, and the residue resulting on the sprayed leaf would obviously impair photosynthesis. A large excess of lime also reduces the concentration of the precipitated copper in the residue and acts as a deterrent to its fungicidal value.

According to Holland (7), the best ratio of milk of lime or hydrated lime to copper sulfate, as judged by suspension, is approximately a 4-2-50 mixture, and this might also be regarded as the lowest ratio practical from the standpoint of safety to the plant. Bordeaux 4-1-50 in practical preparation is not necessarily neutral, while 4-0.7-50 and 4-0.8-50 mixtures, even under laboratory preparation when the strength of the lime is previously determined, may show soluble copper. Practice makes little distinction with regard to the freshness of lime, neither has it adopted any simple qualitative tests to insure against a deficiency of lime. It is necessary, therefore, in practice to adhere rather closely to mixtures with a lime content in sufficient excess to eliminate water soluble copper. If it is true that hydrocyanic acid gas acting on neutral Bordeaux is safe, then the factor of practical preparation of such a mixture becomes important.

The allegation that 4-16-50 and 4-24-50 mixtures are safe with gas if the treated plants are kept dry does not take into consideration prevailing greenhouse conditions, notably high humidity, abundant transpiration, guttation, and high temperatures. There is no assurance of dry foliage even in the absence of wetting; neither are dry conditions under glass conducive to good plant growth.

EXPERIMENTAL METHODS

The cucumber plant was used to identify and measure the degree to which the copper residue is incompatible with gas, because it is extremely sensitive to injury from the combined copper and gas treatments. Potted plants were used. The sprays were applied with a quart atomizer and allowed to dry completely before exposure to gas. The plants were gassed in a tight greenhouse of a volume of 1500 cubic feet. Controls against gas and spray were included in each treatment.

Milk of lime, filtered lime water, and chemical hydrated lime were used with powdered copper sulfate in preparing lime Bordeaux. According to Holland, Dunbar and Gilligan (7) and Holland and Gilligan (10), chemical hydrated lime makes an excellent substitute for quicklime in the preparation of ordinary Bordeaux mixtures, and it is of such purity that it can be substituted pound for pound for quicklime. A chemical hydrated lime having a screen test of 98 per cent through 200 mesh and containing 73.72 per cent calcium oxide was used. When milk of lime was used, it was previously strained through a double thickness of cheesecloth. The method of mixing advocated by Holland, Dunbar and Gilligan (7) was adopted; namely, pouring dilute copper into concentrated lime. Accord-

ing to Butler[1], adding milk of lime to a 4-50 solution of copper sulfate until phenolphthalein paper turns red is more simple, and the mixture is as harmless as a strictly neutral wash. Both methods, however, have practical limitations.

In the experiments reported in this bulletin, different forms of lime and different kinds of base in different ratios with copper sulfate were used. Acid, neutral, and alkaline mixtures of Bordeaux 4-X-50 were prepared with filtered lime water and milk of lime. In many experiments the precipitates were washed on filter paper or by decantation and then brought to volume. Washing was intended to remove the excess of calcium hydroxide and some of the calcium sulfate, on the assumption that these materials might possibly be factors in the incompatibility of the spray with HCN gas.

Calcium cyanide, as Cyanogas, was used as the source of hydrocyanic acid gas in many of the experiments. The following tabulation shows the various ways in which it was used. The size of the fumigating chamber was 1500 cubic feet with a few exceptions which are noted.

Amount Used Grams	Period of Exposure Hours	Interval Between Copper Treatment and Fumigation Hours	Amount Used Grams	Period of Exposure Hours	Interval Between Copper Treatment and Fumigation Hours
4	12	32	7	10	8
4	12	36	7	12	8
5	12	40	8	10	10
5	12	96	10	10	8
6	10	10	10	10	10
6	10	32	10	10	36
6	10	34	25*	10	6
6	10	130	29†	12	8
6	11	8	87†	12	10
6	11	48	*Green house, 5, 000 cubic feet.		
6	12	10	†Greenhouse, 10,000 cubic feet.		

In other experiments, sodium cyanide was used at the rate of ¼ ounce to 1,000 cubic feet and in the generally accepted ratio of 1 ounce of sodium cyanide, 1½ ounces of concentrated sulfuric acid and 2 ounces of water by liquid measure. It is claimed that these proportions produce the maximum volume of gas and carry the reaction to completion. The plants were exposed to the gas as follows, beginning 1 to 2 hours after sundown.

Period of Exposure Hours	Interval Between Copper Treatment and Fumigation Hours	Period of Exposure Hours	Interval Between Copper Treatment and Fumigation Hours
1	8	3	8
2½	8	3	10
3	6	3	32

The greenhouse conditions to which the plants were exposed after gassing varied with the weather, but these were the usual commercial growing conditions prevailing under glass. The foliage of the treated plants was not at any time wetted with water. The results were recorded usually 3 to 6 days after exposure to gas.

Fungicides Employed

In the study of the effect of hydrocyanic acid gas on cucumber plants sprayed

[1]Letter from Dr O. Butler, dated April 22, 1932.

with copper fungicides, consideration was given to most of the diverse forms of copper sprays recommended by investigators or introduced by manufacturers, as classified by Holland and Gilligan (11). The effect of gas on plants sprayed with Bordeaux containing different ratios of lime to copper sulfate was especially investigated. Attention was also given to mixtures prepared with sodium carbonate and sodium hydroxide. Many proprietary Bordeaux substitutes were considered; namely, such brands as Corona, Bowker, Dow, Grasselli, Rex and Riches Piver. Such stainless copper sprays as ammoniacal copper carbonate, Fungtrogen and Hammond's Copper Solution were also tested. Other copper fungicides used were basic and normal copper acetates from the General Chemical Company, copper carbonates from the Corona Chemical Company, basic copper sulfate from Marsh Brothers, and factory-prepared basic copper sulfates of variable copper content prepared with calcium, magnesium, and sodium carbonates, and described by Holland et al. (6, 9).

Since it has been alleged that the reaction of the spray has a great bearing upon its compatibility with gas, the filtrates of the diluted sprays were carefully tested with litmus paper and a freshly prepared 10 per cent solution of potassium ferrocyanide. The chemical test is preferable to litmus for determining the presence of soluble copper and the reaction of the spray, but within narrow limits neither method, of course, indicates the amount of excess base.

RESULTS WITH CUCUMBER PLANTS

Lime with Copper Sulfate

In Table 1 are presented summarized data showing the effect on cucumber plants of a Bordeaux-hydrocyanic acid gas regime in which ratios of lime to copper sulfate were used ranging from 4-0.6-50 to 4-24-50.

When a 4-1-50 mixture was used, injury occurred after gas in each of the thirteen experiments, being severe or very severe in nine, moderate in one, and slight in three of the experiments (Figs. 1, 2). A litmus test of the filtrate applied in five experiments was neutral, and the copper test negative. When mixtures of 4-4-50, 4-8-50, 4-12-50, 4-16-50, and 4-24-50 preceded gas, severe injury occurred in each case (Fig. 1). In some instances injury increased as the ratio of lime to copper sulfate increased from neutral to 4-2-50 mixtures, while higher ratios showed a severe injurious effect which sometimes resulted in the death of the treated plants. The results of other experiments showed that the degree of injury with ratios of 4-1-50 to 4-8-50 was quite similar, or they showed only narrow distinctions (Fig. 1). Mixtures represented by the ratios 4-0.6-50 and 4-0.8-50, which yielded positive tests for copper, were of themselves injurious and the injury was greatly intensified by the action of gas. A 4-0.9-50 mixture prepared with milk of lime, giving a positive test for soluble copper, caused no injury of itself, but very severe injury when followed by gas. A similar mixture prepared with chemical hydrated lime and yielding no soluble copper caused injury with gas but no injury of itself. Thus, in six instances where soluble copper was detected in the diluted spray, the gas either caused or greatly intensified injury. When gas followed such weak Bordeaux mixtures as 1-½-50 (Fig. 2) and 1-1-50, injury resulted and this held as well when the sprayed plants were gassed 130 hours after the copper treatments as after 34 hours. No significant or consistent contrast in injury resulted from substituting milk of lime for chemical hydrated lime in the preparation of Bordeaux. A slight difference, however, in the purity of the lime products employed would be sufficient in the narrow ratios used to account for any slight difference in injury.

Plants sprayed with a 1-50 mixture of slaked pulverized "fat" lime treated with a 1 per cent solution of copper sulfate until neutral to litmus were killed by

TABLE 1. THE EFFECT ON CUCUMBERS PLANTS OF HCN GAS FOLLOWING TREATMENTS WITH LIME BORDEAUX MIXTURES, AND DETERMINATIONS OF SOLUBLE COPPER IN THE RESIDUE

Bordeaux Mixture	Reaction to Litmus	Reaction for Soluble Copper	Injury		Soluble Copper in Residue				HCN in Residue	
					On Leaves		On Glass		On Glass	
			Without HCN	With HCN	Without HCN	With HCN	Without HCN	With HCN	Without HCN	With HCN
4-0.6-50		+	+	+						
4-0.8-50		+	+	+			—	+	—	+
4-0.9-50		±[1]	—	+						
4-1-50	Neutral	—	±[2]	+	±[3]	+	—	+	—	+
4-2-50	Alkaline	—	—	+	—	+				
4-3-50		—	—	+	—	+				
4-4-50		—	—	+	—	+	—	+	—	+
4-4-50 filtered and washed			—	+						
4-4-50 filtrate			—	—						
4-6-50			—	+	—	+				
4-8-50			—	+	—	+	—	+	—	+
4-12-50			—	+	—	+				
4-16-50			—	+			—	+	—	+
4-24-50			—	+			—	+	—	+
1-½-50	Alkaline	—	—	+						
1-1-50			—	+						
1-4-50			—	+						
2-4-50			—	+						
3-4-50			—	+						
4-X-50 (Milk of Lime)	Acid	+	±[4]	+		+				
	Neutral	—	—	+			±[5]	+		
	Alkaline		—	+		+				
4-X-50 (Milk of Lime) washed	Acid	+	—	+						
	Neutral	—	—	+						
	Alkaline		—	+						
4-X-50 (Milk of Lime) filtrate	Neutral	—	—	—						
	Alkaline	—	—	—						
4-X-50 (Filtered Lime Water)	Acid	+	+	+		+				
	Neutral	—	—	+		+				
	Alkaline		—	+		+				
4-X-50 (Filtered Lime Water) Washed	Acid	+	+	+		+				
	Neutral	—	—	+		+				
	Alkaline		—	+		+				
4-X-80 (Filtered Lime Water)	Neutral	—	—	+			—	+		
4-X-100 (Filtered Lime Water)	Neutral	—	—	+						

[1]Two samples prepared with chemical hydrated lime gave a negative reaction for soluble copper; two samples prepared with milk of lime from fresh calcium oxide gave a positive reation.
[2]There was no injury in twelve tests; in one test there was slight injury
[3]No soluble copper in one test; slight trace in two.
[4]No injury in two cases; injury in two cases
[5]Soluble copper in one test; none present in three.

exposure to HCN. When the order of mixing was reversed and a milk of lime suspension was employed, the effect after HCN was the same. A 0.5 per cent solution of copper sulfate neutralized with filtered lime water caused slight injury with HCN. A 1 per cent solution of copper sulfate was neutralized with filtered lime water and allowed to settle. The top, clear liquor was decanted and to the sediment was added fresh water to make 500 cc. When cucumber plants were sprayed with this mixture and then gassed, the injury was moderate to severe. Plants were killed when gas followed the use of a 4-50 solution of copper sulfate neutralized with milk of lime, and were severely injured when gas followed Bordeaux 4-X-50 neutralized with filtered lime water prepared from fresh stone lime.

Acid, neutral, and alkaline 4-X-50 mixtures prepared with milk of lime and filtered lime water, and either used as such or first washed and dehydrated, were compared to determine the influence of the form of lime and the reaction of the spray on the compatibility of the residue with the gas (Tables 1, 5). When acid Bordeaux 4-X-50 prepared with milk of lime was employed, slight injury resulted in two instances and none in two; but on exposure of the sprayed plants to gas, injury resulted in every instance, and it was intensified in the two cases in which the spray itself was injurious. Neutral mixtures of 4-X-50 prepared with milk of lime were safe of themselves, but in every instance they were injurious with gas. Similar mixtures containing sufficient excess lime to give an alkaline test to litmus gave like results. When these mixtures were washed, none caused injury of themselves, even the acid mixtures, yet all of them were injurious when the sprayed plants were exposed to gas. When Bordeaux 4-X-50 was prepared with filtered lime water, only the acid mixtures caused injury of themselves. Injury resulted in every instance where gas acted on neutral or alkaline mixtures, and it was intensified by the action of gas on acid mixtures. Washing the mixtures did not effect any change in these results. Washing and dehydrating a neutral 4-X-50 mixture prepared with milk of lime or filtered lime water (Table 5) then bringing again to volume with water did not make it safe to use, but prolonging the interval between spraying and gassing appeared to remove or lessen the danger of injury. The filtrates of neutral or alkaline Bordeaux 4-X-50 mixtures were compatible with gas, indicating that the incompatible principle is not present in the filtrate and that it is neither calcium hydroxide nor calcium sulfate. (Fig. 3.)

On the basis of this experimentation, it may be concluded that slightly acid or neutral Bordeaux mixtures of lime and copper sulfate which are safe of themselves are positively incompatible with hydrocyanic acid gas; that mixtures with increasing amounts of lime are extremely fatal to cucumbers under commercial conditions of culture; that Bordeaux made with milk of lime or chemical hydrated lime results in more injury when followed by gas than Bordeaux made with lime water, although none are safe. The presence of moisture on the foliage such as would occur from watering is not a necessary factor. Irrespective of the ratio of lime to copper sulfate, injury will occur and the most severe damage may be expected with mixtures containing an excess of lime.

Sodium Carbonate with Copper Sulfate

Burgundy precipitates of different ratios of sodium carbonate to copper sulfate were prepared by adding a cool, dilute solution of copper sulfate to a similar solution of sodium carbonate, then bringing up to volume (Table 2). Burgundy 4-4-50, a strongly alkaline precipitate, was employed three times, causing some injury of itself in two experiments but none in the third. In all three experiments exposure of the sprayed plants to hydrocyanic acid gas was fatal to the plants. Precipitates of 4-2-50 and 4-3-50 ratios, also alkaline to litmus, caused no injury

of themselves; but with gas injury resulted in all instances. An acid 4-X-50 mixture in one experiment was safe of itself but caused severe injury with gas; in another experiment injury was severe both from the spray itself and with gas. When a neutral mixture was employed, slight injury resulted from the spray in one experiment and none in another; but gas in both instances either caused or increased the degree of injury. In one instance a 4-X-50 mixture, containing sufficient excess of sodium carbonate to give an alkaline test with litmus, caused severe burning of itself, and the plants were killed after exposure to gas.

The results with Burgundy precipitates show that the degree of injury following gas is not correlated with any particular reaction of the spray used. The unstable character of this precipitate even in the absence of gas is a sufficient hazard to discourage its use on greenhouse cucumbers.

Table 2. The Effect on Cucumber Plants of HCN Gas Following Treatments with Sal Soda and Caustic Soda Bordeaux Mixtures, and Determinations of Soluble Copper in the Residue.

Fungicide	Reaction to Litmus	Reaction for Soluble Copper	Injury		Soluble Copper in Residue on Leaves	
			Without HCN	With HCN	Without HCN	With HCN
Burgundy Mixture 4-X-50	Acid	+	±[1]	+		
	Neutral		±[2]	+	+	+
	Alkaline		+	+		
Burgundy Mixture 4-2-50	Alkaline	—	—	+	—	+
Burgundy Mixture 4-3-50	Alkaline	—	—	+		
Burgundy Mixture 4-4-50	Alkaline	—	±[3]	+		
Caustic Soda Bordeaux 4-X-50	Acid	+	±[4]	+		+
	Neutral	—	±[5]	+	±[6]	+
	Alkaline		—	+		
Caustic Soda Bordeaux 4-2-50	Alkaline	—	—	+		

[1] Injury in one case; no injury in two.
[2] Slight injury in one case; no injury in one.
[3] Injury or slight injury in two cases; no injury in one.
[4] Injury in two cases; no injury in one.
[5] Injury in one case; no injury in four.
[6] Trace of soluble copper in one case; none in one case.

Sodium Hydroxide with Copper Sulfate

In Table 2 is shown the effect of hydrocyanic acid gas on plants sprayed with sodium hydroxide and copper sulfate in different ratios. When acid 4-X-50 mixtures of caustic soda and copper sulfate were employed, injury resulted from the spray itself in two of three instances. In the third case injury resulted only after exposure to gas. A neutral mixture was used in five experiments, the spray itself causing injury in only one case, but injury resulting from the use of gas in each case. Where alkaline mixtures of 4-X-50 and 4-2-50 ratios were used, injury followed exposure of the sprayed plants to gas, but no injury occurred without gas.

It may be stated that mixtures prepared from sodium hydroxide and copper sulfate, irrespective of the reaction of the spray, are not safe with HCN on cucumbers, and it is concluded that the ratio of sodium hydroxide to copper sulfate does not materially influence the degree of injury.

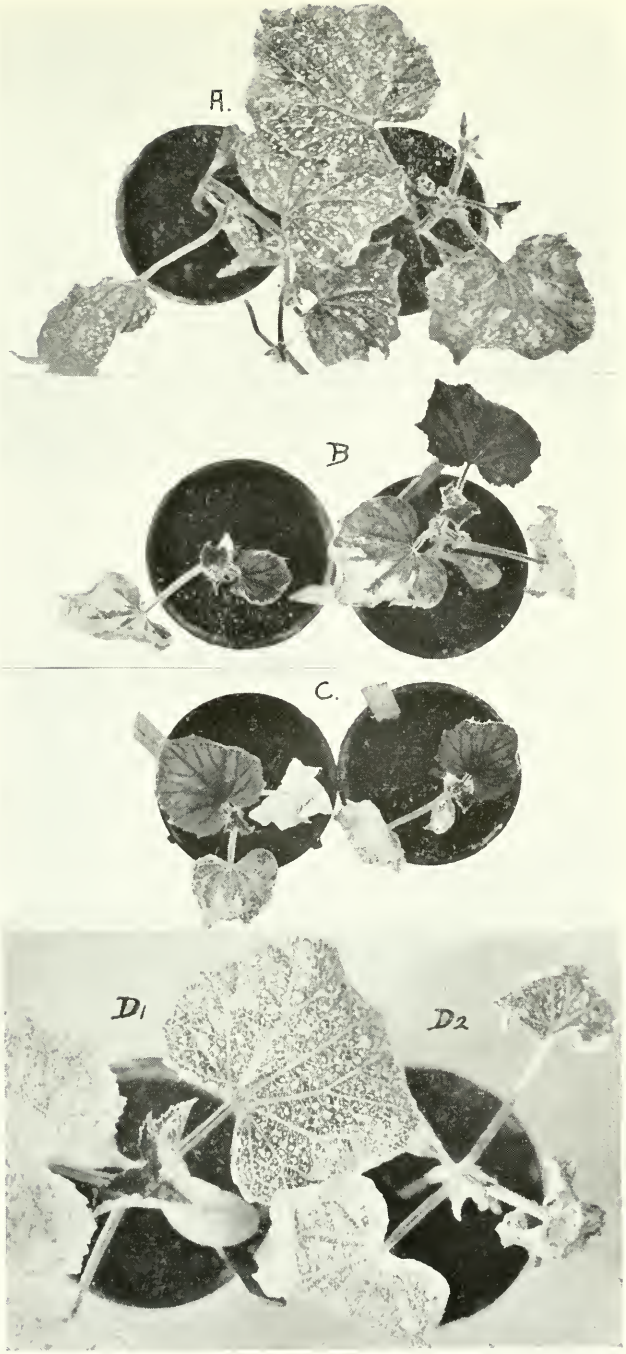

Figure 1.—Cucumber Plants Sprayed with Bordeaux and Gassed with HCN.
A, Bordeaux 4-1-50; B, 4-4-50; C, 4-8-50; D1, 4-24-50 without HCN; D2, 4-24-50 with HCN. Note that injury has occurred with all mixtures when followed by gas.

Figure 2.—Cucumber Plants Sprayed with Bordeaux and Gassed with HCN.
A, Bordeaux 4-1-50; B, 1-½-50; C, Control, gassed only. Note that neither Bordeaux 4-1-50 nor Bordeaux 1-½-50, which contains an excess of lime but only one-fourth as much copper sulfate, is safe with gas.

Figure 3.—Cucumber Plants Sprayed with Bordeaux and Gassed with HCN.
A, sprayed with filtrate of neutral Bordeaux 4-X-50; B, Control gassed only; C, sprayed with washed residue of neutral Bordeaux 4-X-50; D, complete spray of neutral Bordeaux 4-X-50. The incompatible component of the spray is in the washed residue and not in the clear filtrate.

Figure 4.—Cucumber Plants Sprayed with Normal and Basic Copper Acetates and Gassed with HCN.

A, a 0.5 per cent solution of basic copper acetate (34.4 per cent Cu); B, a 0.34 per cent solution of basic copper acetate (48 per cent Cu); C, a 0.54 per cent solution of normal copper acetate (31.8 per cent Cu). Right, gassed with HCN; left, not gassed.

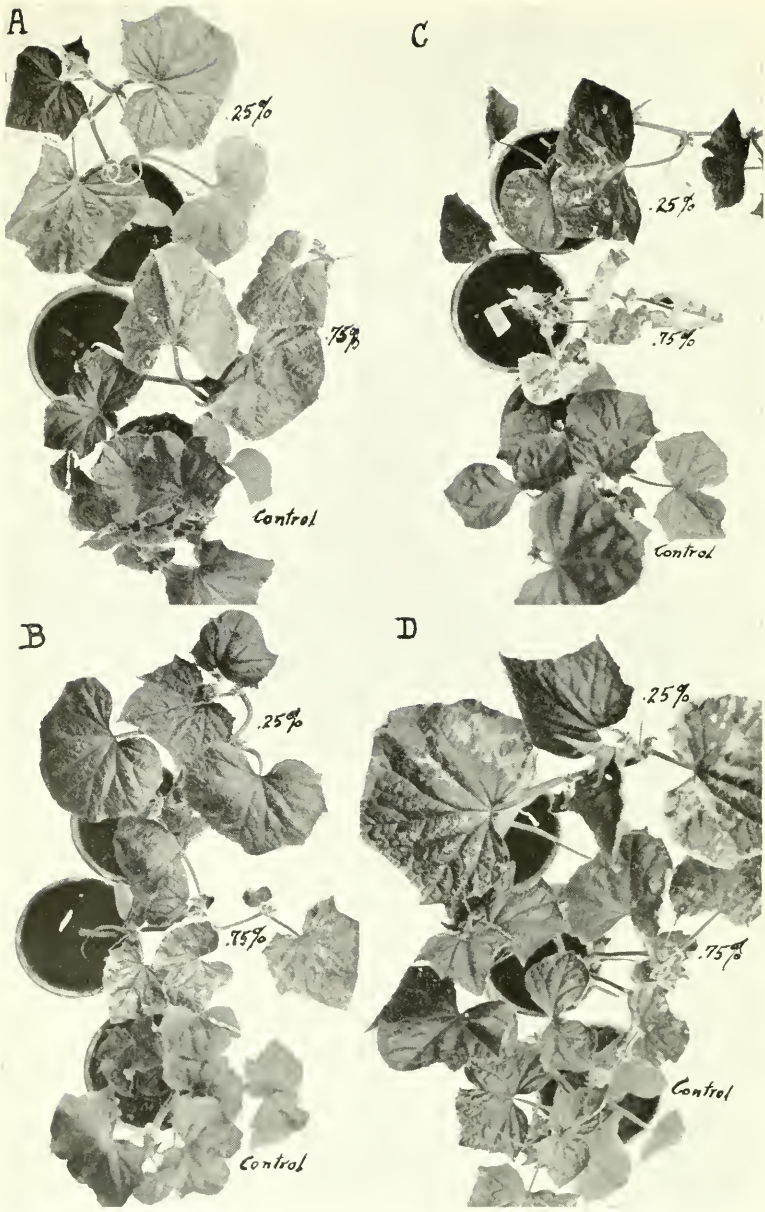

Figure 5.—Cucumber Plants Sprayed with Normal and Basic Copper Acetates of 0.25 and 0.75 Per Cent Strengths and Gassed with HCN.

A, basic copper acetate (34.4 per cent Cu) without gas; C, with gas; B, normal copper acetate (31.8 per cent Cu) without gas; D, with gas. All controls gassed only. Injury occurs after the action of gas, irrespective of the presence of alkali in the spray.

Dry Bordeaux Substitutes

In Tables 3 and 5 are presented the results of the use of HCN gas on cucumber plants previously sprayed with proprietary Bordeaux powders. These sprays were prepared to contain the same amount of copper that is present in 4 pounds of crystalline copper sulfate in 50 gallons of Bordeaux. The Dow and Rex brands of Bordeaux powders are slightly alkaline. The Corona, Riches Piver, Grasselli, and Bowker brands are more strongly alkaline to litmus. In every case severe injury occurred after the sprayed plants were gassed. This fact, however, is not to be construed as casting any reflection upon these materials as fungicides when used in the absence of gas. The reaction of these sprays within the limits shown by a litmus paper test was not a factor in influencing the degree of injury.

Table 3. The Effect on Cucumber Plants of HCN Gas Following Treatments with Certain Proprietary Copper Fungicides, and Determinations of Soluble Copper in the Residue.

Fungicide	Active Cu Content Per Cent	Reaction to Litmus	Reaction for Soluble Copper	Injury		Soluble Copper in Residue			
						On Leaves		On Glass	
				Without HCN	With HCN	Without HCN	With HCN	Without HCN	With HCN
Basic Copper Sulfate	26.31	Neutral	—	—	—	—	±[1]	—	±[2]
Basic Copper Sulfate	52.95	Neutral	—	—	—				
Basic Copper Sulfate	53.31	Neutral	—	—	—				
Basic Copper Sulfate plus 0.1% Chem. Hyd. Lime	26.31	Alkaline	—	—	+	—	+		
Basic Copper Sulfate plus 0.2% Chem. Hyd. Lime	26.31	Alkaline	—	—	+				
Basic Copper Sulfate plus 0.5% Chem. Hyd. Lime	26.31	Alkaline	—	—	+	—	+		
Basic Copper Sulfate plus 1.0% Chem. Hyd. Lime	26.31	Alkaline	—	—	+	—	+		
Chem. Hyd. Lime 0.2%, 0.5%, 1.0%		Alkaline	—	—	—				
Bordow (Dow)	12.75	Alkaline[3]	—	—	+	+[4]	+	—	+
Bordeaux Mix. Pow. (Grasselli)	13.	Alkaline	—	—	+				
Bordo Mix. (Rex)	16.	Alkaline[3]	—	—	+				
Corona Copper Carbonate	50.	Neutral	—	—	—				
Corona Copper Carbonate	18.	Neutral	—	—	±[5]	+[4]	±[6]	—	±[7]
Bordeaux (Riches Piver)	12.75	Alkaline	—	—	+				
Dry Bord. Mix. (Corona)	13.	Alkaline	—	—	+				
Dry Pow. Bord. (Bowker)	13.	Alkaline	—	—	+				

[1] Trace of soluble copper in three cases; none in one.
[2] Trace of soluble copper in five cases; none in two.
[3] Only slightly alkaline.
[4] Slight trace of soluble copper in one case.
[5] Trace of injury in one case; none in three.
[6] Soluble copper in two cases; none in one
[7] Trace of soluble copper in one case; none in one.

Factory-made basic copper sulfates, the preparation of which is fully reported by Holland et al. (6, 9), caused no injury of themselves or with gas. These sprays are neutral to litmus and were prepared with calcium carbonate, magneisum carbonate, or sodium carbonate. In preparation the heated precipitates are washed practically free of soluble by-products, i.e., magnesium and sodium sulfates, then dried and air separated. The addition of chemical hydrated lime, in 0.1, 0.2, 0.5, and 1.0 per cent strengths, to diluted 26 per cent basic copper sulfate caused injury with gas which was most severe, generally considered, with the highest amounts of lime added. Corona copper carbonate powders, containing 18 per cent and 50 per cent copper, and basic copper sulfate (Marsh Bros.), containing 53 per cent copper, are neutral to litmus and were also safe with gas. The Corona 18 per cent product is similar in preparation to the 26 per cent basic copper sulfate, and the Corona 50 per cent product to the 53 per cent basic copper sulfate. Greater stability is obtained in the manufacture of basic copper sulfates and carbonates by heating the precipitates, and this appears to explain their safety with HCN. The Marsh Bros. product is produced by the action of ionized copper sulfate or of sulfuric acid on metallic copper and contains no by-products.

Stainless Copper Sprays

This group includes copper acetate (Table 4), Hammond's Copper Solution, Fungtrogen, and copper sulfate.

Table 4. The Effect on Cucumber Plants of HCN Gas Following Treatments with Certain Stainless Copper Sprays.

Fungicide	Active Cu Content Per Cent	Concentration	Reaction to Litmus	Reaction for Soluble Copper	Injury	
					Without HCN	With HCN
Hammond's Copper Sol.	3.04	a	Alkaline	—	—	±
Fungtrogen	0.47	b	Alkaline	—	—	—
Ammoniacal Copper Carbonate		c	Alkaline	—	—	—
Basic Copper Acetate	34.4	d	Acid	+	±	+
Normal Copper Acetate	31.8	e	Acid	+	±	+
Copper Sulfate .01% Sol.			Neutral	Trace	—	—
Copper Sulfate .02% Sol.			Neutral	Trace	—	—
Copper Sulfate .03% Sol.			Neutral	Trace	—	—
Copper Sulfate .05% Sol.			Neutral	Trace	—	—
Copper Sulfate .07% Sol.			Acid	Trace	—	—

a—1-80 in 4 instances; 1-40 (double the manufacturer's recommendation) in one. Slight injury occurred in two cases at the 1-80 concentration; no injury in the other cases.
b—1-60 in 3 instances; 1-30 (double the manufacturer's recommendation) in one.
c—NH_4OH 0.8% with $CuCO_3$ 0.24, 0.16, and 0.08 % by weight.
d—0.25, 0.50, and 0.75 % by weight. Injury without HCN in 2 cases; no injury in 4 cases.
e—0.25, 0.50, 0.65, 0.75, and 0.80 % by weight. Injury without HCN in 2 cases; no injury in 3 cases.

Basic copper acetate, containing 34.4 per cent copper, and normal copper acetate, containing 31.8 per cent copper, were used. Both forms gave positive tests for soluble copper and acid reactions to litmus. Basic copper acetate was used at strengths of 0.25, 0.50, and 0.75 per cent by weight, and normal copper acetate at strengths of 0.25, 0.50, 0.65, 0.75, and 0.80 per cent. Since both products contain over 30 per cent of copper, a concentration of 0.25 per cent would contain over 0.07 per cent copper, which would seem fairly reasonable, although references state that they have been used at concentrations ranging from less than 0.1 to 1

TABLE 5. THE EFFECT ON CUCUMBER PLANTS OF HCN GAS FOLLOWING TREATMENTS WITH COPPER FUNGICIDES

Fumigation Treatment	I	II	III	IV
Cyanogas Used.....grams	4½	4½	4½	5
Period of Exposure.....hours	10	12	10	10
Interval Between Copper Treatment and Fumigation.....hours	9	32	57	105

Copper Treatment	Type of Injury After Exposure to HCN Gas			
	I	II	III	IV
No treatment	Slight	None	None	None
Basic Copper Sulfate 26%	Slight yellowing of leaf margins	None	None	None
Corona Copper Carbonate 18%	None	None	None	None
Basic Copper Sulfate 53% (Marsh)	Slight	None	None	None
Neutral Bordeaux 4-X-50 (Milk of Lime)	Severe to very severe	Moderate to severe	Slight to moderate	Slight
Neutral Bordeaux 4-X-50 (Milk of Lime) washed	Very severe	Moderate	Moderate	Slight
Neutral Bordeaux 4-X-50 (Milk of Lime) washed, dried and brought to volume	Moderate to severe	Slight trace	None	None
Neutral Bordeaux 4-X-50 (Filtered Lime Water)	Very severe	Severe or very severe	None	None
Neutral Bordeaux 4-X-50 (Filtered Lime Water) washed	Very severe	Severe	Slight	Very slight
Neutral Bordeaux 4-X-50 (Filtered Lime Water) washed, dried and brought to volume	Trace; chronic yellow along margins	Slight; chronic yellow	Trace to slight	None
Bordeaux 4-4-50 Chem. Hyd. Lime	Killed	Very severe	Moderate	Moderate to severe

per cent with no well-defined practice. Basic copper acetate was injurious in two out of six experiments, and normal copper acetate in two out of five (Fig. 4). This may have been due to some difference in the amount of spray applied or to variations in atmospheric conditions in the greenhouse. Injury followed the exposure of the sprayed uninjured plants to gas; and in those instances where injury resulted from spraying, it was intensified by the action of gas. The soluble copper salt formed by the action of gas was much more toxic than copper acetate itself. A 0.25 per cent dilution was less injurious than higher concentrations, this also holding true with gas (Fig. 5).

Copper sulfate in 0.01, 0.02, 0.03, and 0.05 per cent solutions was neutral to litmus but gave faint positive chemical tests for soluble copper. A 0.07 per cent solution was acid to litmus. In none of the experiments were cucumber plants injured by copper sulfate sprays used alone in these concentrations or by the exposure of the sprayed plants to gas. It is evident, therefore, that cucumber plants will tolerate a small amount of water soluble copper without manifesting injury.

Hammond's Copper Solution, an ammoniacal copper concentrate guaranteed to contain 3.05 per cent active copper, was not injurious to cucumbers of itself

at dilutions of 1-80 and 1-40, but slight injury followed the use of gas in two cases out of five. Lack of injury beyond a slight degree in two instances is attributed to the relatively small concentration of copper present as compared to a 4-50 strength of copper sulfate in Bordeaux. Stronger solutions were unsafe for cucumber plants.

Fungtrogen, containing 0.47 per cent active copper and 0.47 per cent nickel and alkaline to litmus, caused no injury of itself or with HCN at dilutions of 1-30 and 1-60. The low concentrations, like the low concentrations of copper sulfate, undoubtedly account for its safe use with gas.

Laboratory-prepared ammoniacal copper carbonate was not toxic to cucumber plants of itself or with HCN in any strength of copper carbonate ranging from 0.08 to 0.24 per cent in 0.8 per cent ammonium hydroxide solution.

It is evident from these results that more than mere traces of soluble copper must result from the action of gas on copper residues in order to cause injury, and that the copper content of the fungicide is a contributing factor in the reaction.

Lime

When sprays of chemical hydrated lime of 0.2, 0.5 and 1 per cent strengths were used, no injury occurred from the sprays either alone or with gas.

EFFECT OF HYDROCYANIC ACID GAS ON COPPER SPRAY RESIDUES

On Cucumber Leaves

An explanation for injury to sprayed plants from the action of HCN gas on the spray residue was sought in qualitative tests of the residue after fumigation. The dry spray residues from the surface of 10 grams of leaves were carefully collected with distilled water, the washings filtered, and the filtrate tested for soluble copper with potassium ferrocyanide.

The residues of Bordeaux on cucumber leaves acted upon by HCN gas yielded positive tests for water soluble copper (Table 1). In three experiments a test was made of the residue of Bordeaux 4-1-50, a neutral mixture, on cucumber leaves. In one of three instances in which the plants were not exposed to gas, no soluble copper was found, and in the other two only a slight trace; while the action of the gas resulted in the presence of much soluble copper and in injury in all three instances. Bordeaux mixtures containing higher amounts of lime, e.g., 4-2-50, 4-3-50, 4-4-50, 4-6-50, 4-8-50, and 4-12-50, when exposed to gas yielded soluble copper, and cucumber foliage was injured in every instance. The degree of injury and the amount of soluble copper in the residue increased as the ratio of lime to copper sulfate was increased. The residues of neutral and alkaline Bordeaux 4-X-50 mixtures, prepared with milk of lime or filtered lime water and either washed or not, consistently yielded soluble copper after the action of gas, and its presence was associated with foliage injury. Similarly the residue of a neutral 4-X-50 Burgundy mixture yielded but a trace of soluble copper, while the action of gas resulted in much of it; and the residue of neutral caustic soda Bordeaux 4-X-50 showed only a trace of soluble copper in one instance and none in the other, while after the action of gas strong tests were obtained in both cases (Table 2).

The results with basic copper sulfates (Table 3) are particularly interesting because the lack of injury from these materials was definitely correlated with the compatibility of their residues on leaves with gas. In three of four tests only a trace of copper was detected, and in the fourth test none. However, when chemical hydrated lime was added to basic copper sulfate and the sprayed plants exposed to gas, good tests for soluble copper were obtained in each of seven experiments,

indicating the influence of excess base as a contributing factor in the production of soluble copper. Injury occurred only when lime was added to the basic copper sulfates, and the amount of soluble copper found increased in proportion to the amount of lime added. Corona 18 per cent copper carbonate with gas gave positive tests for copper in leaf residues in two instances and none in the third, but no foliage injury resulted in either of the cases where soluble copper was found.

There is sufficient evidence here to affirm that the fact that a copper spray is neutral or approximately neutral in laboratory preparation is no insurance against the production of soluble copper on the leaf and consequent injury. Factory-prepared basic copper sulfates and carbonates are safe, apparently because of their greater stability.

On Glass

In the previous section it was shown that the copper residue on the sprayed leaf gives rise to a soluble copper salt in the presence of HCN. This may indicate the participation of the plant itself in the reaction, for according to Crandall (2), Holland, Dunbar and Gilligan (8), and Pickering (12), complex soluble cupric compounds of copper may be produced from copper fungicides by alkali and exudation products of the plant, or by osmosis of the cell contents such as sugars, hydroxy-organic acids, and biuret compounds. It is also possible that certain inconsistencies in the tests for soluble copper in the residues on leaves may be correlated with leaf action, although other factors such as dosage, period of exposure, atmospheric conditions, and any narrow differences arising in the compounding of the sprays are also to be considered as contributing factors. As a matter of investigation, panes of glass 16 by 30 inches were sprayed with Bordeaux mixtures of different ratios of lime, ranging from neutral to 4-24-50 mixtures, and allowed to air dry. Exposure to gas was over night. Controls against the action of gas were included in each experiment. The dry residues were removed and examined for color, soluble copper, and HCN.

A given weight of dry residue, generally 1/10 gram, was macerated in water and tested for soluble copper. Another 1/10 gram of residue was macerated with water and tested for hydrocyanic acid.

Dry residues of Bordeaux, increasing in ratios of lime from neutral to 4-24-50 mixtures exhibited increasing intensities of blue color ranging from pale nile or lumiere blue to pale king's blue, according to the color chart of Ridgway (14). Parallel residues of the same mixtures exposed to gas exhibited colors of rejane and deep lichen green (4-0.8-50 to 4-4-50); glaucous, pale glaucous green, corydalis green, and yellowish glaucous (4-4-50 to 4-16-50); and pale dull glaucous blue (4-24-50). Butler and Jenkins (1) obtained brown precipitates on passing hydrocyanic acid gas into toxic Bordeaux mixtures and white precipitates with non-toxic mixtures such as 1:0.2 and 1:6. In the experiments of the writers, brown or white residues were never obtained when gas acted on Bordeaux on glass, irrespective of the ratio of the base to copper sulfate. Therefore, if brown precipitates suggest cupric cyanide and white precipitates cuprous cyanide, neither of these compounds was present. Bordeaux mixture increasing in ratios of lime from 4-0.8-50 to 4-24-50 showed soluble copper and HCN in residues on glass after exposure to gas in each of sixteen tests. The neutral mixtures prepared with milk of lime and chemical hydrated lime were no exception (Table 1). Parallel residues not exposed to gas were in every instance free of soluble copper and HCN. The change in color of the residue on exposure to gas, therefore, is correlated with the production of soluble copper, although the color could not be considered a safe guide as to the amount present. Butler and Jenkins contend that Bordeaux 1:0.2 and 1:6 ratios do not give off detectable amounts of cyanogen,

while 1:1 and 1:2 ratios give off the largest amounts and most rapidly. In the present experiments, all of the gas-treated residues contained hydrocyanic acid gas and this increased with the amount of lime in the Bordeaux.

The results indicated that an increase in the ratio of lime from neutral to 4-8-50 and 4-12-50 resulted in a corresponding increase in the amount of soluble copper and HCN. Further increase in the ratio of lime up to 4-24-50 resulted in a gradual decrease in the amount of soluble copper, but did not render the spray and gas regime safer to cucumber plants. Since qualitative analyses of the residues were based on an equal weight, namely 1/10 gram, the copper content obviously should vary with the concentration of lime. Assuming that 4 pounds of crystalline copper sulfate (25.46 per cent Cu) are employed in preparing Bordeaux, then the amount of copper in the residue would vary with the proportion of lime. The applications, although approximately of the same value of Bordeaux in each case, are therefore not directly comparable as regards the relative amounts of soluble copper found. This fact accounts for an eventual decrease in the amounts of soluble copper as the lime content is increased above ratios of 4-8-50 and 4-10-50, based on an equal weight of the dry samples analyzed.

Dow Bordow, which is an alkaline proprietary copper powder, yielded considerable soluble copper on exposure to gas, but none by itself in two parallel tests (Table 3). Being alkaline, these powders behave like Bordeaux mixtures containing an excess of lime.

The residue of factory-made basic copper sulfate (26.31 per cent Cu) on glass when exposed to HCN never yielded sufficient soluble copper to cause injury. When residues were exposed to gas, a trace of soluble copper was found in five instances and none in two. No soluble copper was found in any of the residues not exposed to gas. The results with Corona copper carbonate (18 per cent Cu) were similar.

Three tests of the residues of neutral Bordeaux 4-X-50 prepared with milk of lime showed no soluble copper; but after exposure to gas, soluble copper was present in all three, although in one case there was only a trace (Table 1). In another comparative test of this mixture, soluble copper was found in both residues, but that acted upon by HCN contained the greater amount. When residues of neutral 4-X-50 mixtures prepared with filtered lime water were compared, a trace of copper was found only in residues exposed to gas, and in each instance the Bordeaux and gas regime caused injury to cucumber foliage.

The analysis of spray residues on glass offered more consistent results than on leaves, indicating some influence of the respiratory or transpiratory products or of exudation of the leaf itself.

The action of HCN gas on factory-prepared neutral basic copper sulfates and carbonates did not produce sufficient soluble copper to cause injury to cucumber plants. Gas reacted with neutral laboratory-prepared Bordeaux, and the amount of soluble copper formed appeared to be greater when dispersed lime was used in preparation, e.g., milk of lime or chemical hydrated lime, than when a solution of lime such as filtered lime water was used, but the nature of the base did not remove the hazard of injury. Laboratory preparation in the cold produces less stable copper sulfates than heating which is the practice in the manufacture of commercial sulfates and carbonates; while washing, dehydration, and air separation of the commercial sulfates and carbonates are considered less important factors contributing to their safety with HCN gas. The results show beyond doubt that homemade neutral Bordeaux 4-X-50, even if its preparation were practical, is not safe with gas.

It is logical to assume that a soluble double salt is formed in all cases when hydrocyanic acid gas acts on Bordeaux mixture and that the amount varies with the amount of free base, the concentration of the gas, the period of exposure to

gas, the conditions favoring absorption of the gas, and the greenhouse temperatures after gas. Water soluble copper would seem to preclude cuprous and cupric cyanides also, since both are insoluble in water, according to Williams (15, p. 48-49) and Hodgman and Lange (5, p. 102, 103). Cuprous cyanide readily dissolves in solutions of alkaline cyanides with which it forms a number of crystalline double salts. The calcium salt $CaCu_2(CN)_4 5H_2O$, according to Williams (15) is very soluble in water. The injurious compound formed when gas acts on Bordeaux is presumably calcium cuprocyanide or some similar product. An equation showing the procedure in the reaction, or a more definite opinion regarding the formula of the toxic substance would be dangerous without more confirmatory laboratory work, and is not needed from a practical point of view.

CONCLUSION

The presence of free lime or soda in the copper spray increases the degree of injury; but injury may occur without it as is demonstrated by the behavior of acid Bordeaux mixtures prepared with lime or soda, the acid basic and normal copper acetates, and neutral Bordeaux 4-X-50 mixtures prepared with milk of lime or filtered lime water. The danger of injury from the use of insufficient lime would be as great as the danger from a slight excess. Therefore, if fungous diseases are of sufficient importance in the greenhouse to warrant the use of copper fungicides, fumigation with hydrocyanic acid gas should precede the application of copper; or only commercial basic copper carbonates, basic copper sulfates, or non-staining ammoniacal copper sprays should be used.

SUMMARY

Cucumber plants were not injured when sprayed with Corona copper carbonate (18 or 50 per cent Cu) or commercial basic copper sulfates (26.31, 52.95, or 53.31 per cent Cu) followed by hydrocyanic acid gas. These diluted sprays are neutral to litmus. Laboratory-prepared neutral Bordeaux mixtures with gas were injurious.

When cucumber plants were sprayed with basic copper sulfate to which chemical hydrated lime had been added, injury followed the use of gas and increased proportionately with the alkali present.

When cucumber plants were sprayed with acid copper fungicides, i.e., normal and basic copper acetates, acid Bordeaux prepared with calcium hydroxide, sodium carbonate, or sodium hydroxide, injury resulted from or was intensified by an application of gas.

Copper sulfate solutions containing 0.01, 0.02, 0.03, 0.05, or 0.07 per cent copper sulfate were not injurious to cucumber plants when used alone or followed by gas.

Cucumber plants were injured when gas followed spraying with copper fungicides containing calcium hydroxide, sodium hydroxide, or sodium carbonate, even when the alkali component was reduced to yield mixtures neutral to litmus.

Injury occurred whether hydrocyanic acid gas was evolved from calcium cyanide (Cyanogas) or from sodium cyanide, and whether chemical hydrated lime, milk of lime, or filtered lime water was used in the preparation of Bordeaux.

The spray residue from injured leaves yielded water soluble copper; and the amount of soluble copper and the degree of injury in general tended to increase in proportion to the amount of alkali present in the fungicide within the limits of ordinary ratios of base to copper sulfate.

Residues of Bordeaux on glass, acted upon by gas, yielded both soluble copper and hydrocyanic acid gas. These occurred in a fairly constant ratio and increased

in proportion to the amount of alkali present. A large excess of alkali reduced the concentration of precipitated copper in the spray and consequently the amount of soluble copper in the gassed residues.

The toxic salt is presumably calcium cuprocyanide $CaCu_2(CN)_4 5H_2O$ or a similar soluble copper salt of cyanide.

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Publication of this Document Approved by Commission on Administration and Finance
3M-1-'34. No. 268.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 304 DECEMBER, 1933

Secondary Milk Markets in Massachusetts In the Period of Falling Prices 1930 - 1932

By David Rozman

During the past few years, and especially since the beginning of the business depression and falling prices, there has been considerable dislocation of milk marketing machinery in small markets of Massachusetts on account of changing local conditions and increased competition from outside areas. In this study of secondary milk markets a special investigation was made in three cities with the object of analyzing their milk marketing set-up and outlining the most important problems facing both producers and distributors.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

SECONDARY MILK MARKETS IN MASSACHUSETTS IN THE PERIOD OF FALLING PRICES, 1930-1932

By David Rozman, Assistant Research Professor of Agricultural Economics

INTRODUCTION

The competitive conditions of milk marketing in Massachusetts, prevalent for some time in the large cities of the state, have spread within recent years into smaller communities previously dependent almost entirely on nearby producers for their supply of milk. Although there has always been a certain degree of dependence of small milk markets on conditions in Boston and other large cities in the State, not until the beginning of the present depression did it become especially prominent. The price structure of these markets has been affected by the pressure of an additional supply of outside milk as well as by the changing methods of local milk distribution, characterized by the attempt of an increasing number of local producers to enter the distributing field to take advantage of the spread between prices received for their milk from dealers and those prevailing in retail distribution.

As a result of various forces, a complete breakdown of marketing machinery occurred in a number of small markets during 1932, causing large losses both to the producers and to the distributors.

In many small markets there has been a considerable increase in new regulations for the sale of milk designed to prevent the influx of outside milk and to keep within reasonable bounds the rapid movement of producers into the distributing field. However, in most cases the restrictions both in price and in sources of supply proved to be effective only for a short time, and led eventually to greater dislocation of local markets by preventing the readjustments which had to take place in the face of the fall of purchasing power of consumers and general unemployment.

Method of Investigation

In the summer and fall of 1932 a special investigation was made in three cities situated in different parts of the state—Gardner, with a population of 19,399; Attleboro, with 21,769; and Newburyport, with 15,084—with the object of studying their milk marketing set-up and analyzing the changes which have taken place since 1930. The information was collected on the basis of a questionnaire through personal visits to all the distributors and producers in Gardner market and to the dealers and distributors in the other two cities. The main points covered included supply and sale of milk, location of producers and distributors, and marketing machinery with price plans of producers, dealers, and other distributing agencies. Special emphasis was placed on information indicating the position of producer-distributors in the distributing field and their relation to the maintenance of an orderly and stable market in these communities.

Regulations for the Sale of Milk

In addition to the general state regulations for the production and sale of milk, the three cities through their boards of health adopted certain rules in regard to producers and distributors to be enforced by the local milk inspectors. The latter were vested with authority and responsibility for seeing that the milk sold should come from inspected and approved dairies and should satisfy the requirements as to quality. As representatives of the Board of Health they were authorized to issue permits to new distributors after satisfying themselves that the conditions of production, milkrooms, and plants came up to the required standards.

In the past few years, and especially since the beginning of the depression and rapid changes in the condition of supply, the regulations as to production and distribution in these markets have become more numerous and more stringent. In the Gardner market the regulations of the Board of Health stipulated that no milk should be sold in that city unless it came from farms inspected and approved by the local milk inspector. This precluded the dealers from obtaining their milk outside of the local milk shed and confined their supply to nearby producers. Another important requirement adopted in 1931 was that the milk sold should either be pasteurized or come from tuberculin-tested cows.

In Attleboro and Newburyport markets the farms supplying milk for distribution were likewise subject to inspection and approval by the local milk inspector, this rule being applied with special rigor in the case of application for licenses to sell milk by new distributors. However, in the case of several distributing agencies which were in the market prior to the introduction of the new restrictions, milk was allowed to be brought from outside the local milk shed. Both raw and pasteurized milk were allowed to be sold in these markets, but according to a new ruling adopted by the Board of Health, only pasteurized milk will be sold in Attleboro market beginning with 1934.

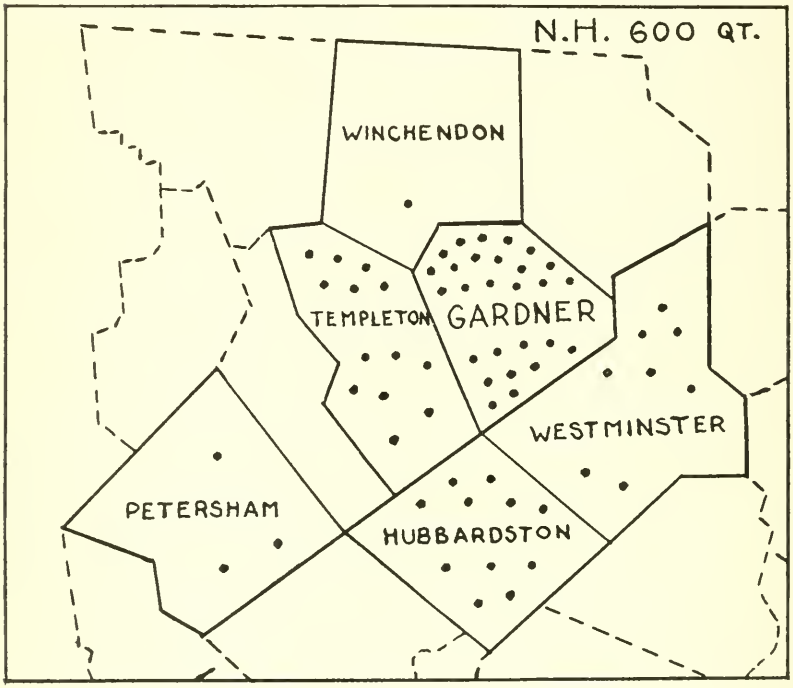
In addition to the regulations of the Board of Health the conditions of the sale of milk in the Gardner and Attleboro markets were affected by the policies and rules of conduct adopted by the organizations of distributors operating in these markets.

SOURCES OF MILK SUPPLY

Under the established system of local regulation, the milk supply for these markets came from the nearby towns, except for small amounts brought by the dealers from more distant points. The location of towns and the amounts of milk produced in them for each of the three cities is indicated on the accompanying maps. Inasmuch as some of the distributors were selling their milk in several adjoining markets, adjustments were made to include only the portion of the supply sold in the market under consideration. The amount of milk obtained from outside of the state is also indicated on the map for each market.

In the Gardner market, in addition to 26 producers retailing milk, there were 73 producers selling their milk to distributors. All of the producers, except for a few from New Hampshire, were located in the adjoining towns. The milk for Attleboro was produced by 35 producers engaged in distribution and 49 local producers supplying distributors. The Newburyport market was supplied by 17

producers in the distributing field and 70 local producers selling their milk to distributors. In addition about 20 per cent of the milk in Attleboro market and 10 per cent in Newburyport market came from producers located outside of the state.

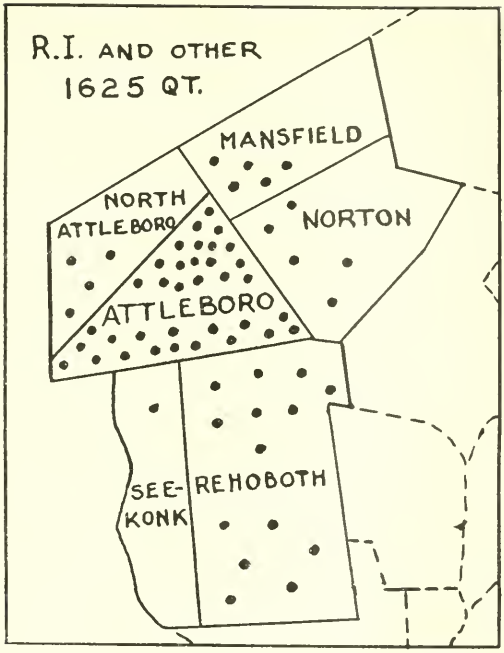


Map 1.—Sources of Milk Supply in Gardner
1 dot = 100 quarts.

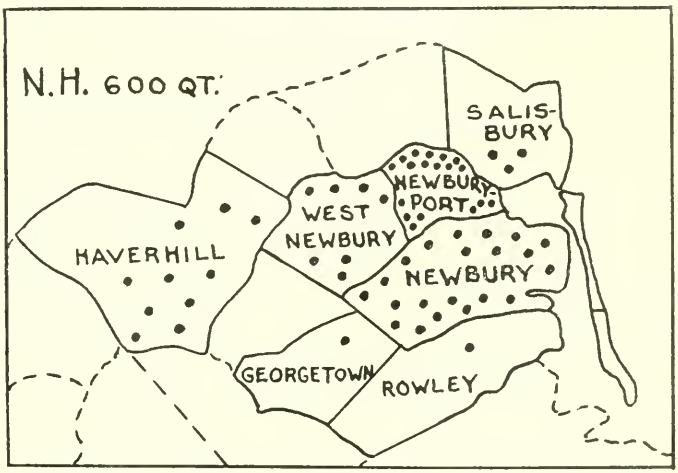
Production and Purchase of Milk by Producer-Distributors

The highest proportion of milk purchased by producer-distributors in relation to their own production was found in Newburyport market, where these two items were about equal. It is to be noted (Table 1), however, that there has been a considerable decline in the amount of purchased milk since 1930, while the output of milk by producer-distributors has remained stable. The falling off in the sales of milk in the Newburyport market affected, therefore, in the first place the producers, who were confronted with the problem of disposing of their surplus in the absence of an adequate outlet for their milk. This situation was aggravated by the fact that the loss of business by producer-distributors in that area was in favor of several distributing agencies obtaining their milk largely outside of the local milk shed.

In the Attleboro market both the production and purchase of milk by producer-distributors have remained on about the same level since 1930. The purchase of



Map 2.—Sources of Milk Supply in Attleboro.
1 dot = 100 quarts



Map 3.—Sources of Milk Supply in Newburyport.
1 dot = 100 quarts.

milk by distributors, however, was lower in relation to their own production than in the other two areas. Although the purchase of milk by producer-distributors in the Gardner market has increased since 1930, their dependence on the purchased milk has not reached the same level as in the Newburyport market. A considerable decline in production and purchase of milk by the Gardner producers in 1931 was caused by the newly introduced regulations of the Board of Health, which forced some of the producer-distributors to buy milk from the pasteurizing plants. In the face of falling prices and sales of milk the general tendency among producer-distributors at the time of the investigation was to curtail the purchase of milk and maintain or even increase their own production.

Table 1. Daily Production and Purchases of Milk by Producer-Distributors

Year	Milk Produced Daily		Milk Purchased Daily	
	Number of Producer-Distributors	Quarts	Number of Producer-Distributors	Quarts
		Attleboro		
1930	33	3,873	6	615
1931	36	4,168	7	635
1932	35	3,724	8	675
		Gardner		
1930	23	2,886	7	602
1931	21	2,555	10	1,125
1932	26	3,096	12	994
		Newburyport		
1930	16	1,407	13	1,921
1931	16	1,287	13	1,721
1932	17	1,404	11	1,420

Size of Herds Owned by Producer-Distributors

The distribution of the number of cows owned by producer-distributors indicates that most of them kept small herds. (Table 2.) More than half of the producer-distributors in Attleboro and Newburyport markets and about one-third in Gardner had 9 or less cows each. Only 7 producers in Gardner and Attleboro areas and 3 in Newburyport area had 20 or more cows each. On the average the largest herds of cows were found in Gardner area with about 16 cows per producer-distributor, and the smallest in Newburyport area with about 11 cows.

Since 1930 the size of herds owned by individual producers at any particular time has undergone considerable change owing to the application of the tuberculin test. In spite of considerable elimination caused by the test, practically all the producers have brought their herds to the previous size or even increased them.

TABLE 2. NUMBER OF COWS OWNED BY PRODUCER-DISTRIBUTORS

Distribution of Cows	Attleboro		Gardner		Newburyport	
	Number of Producer-Distributors	Total Number of Cows	Number of Producer-Distributors	Total Number of Cows	Number of Producer-Distributors	Total Number of Cows
Below 5	6	18	2	8	1	1
5- 9	15	108	7	50	8	50
10-14	5	63	6	68	3	37
15-19	2	33	4	68	2	34
20 or over	7	259	7	209	3	69
Total	35	481	26	403	17	191

Sales of Other Products by Producer-Distributors

In addition to the sale of milk many producer-distributors sold some other products from their farms. Such products as cream and eggs were ordinarily distributed to customers on the regular retail route, while poultry and vegetables were largely sold from the farm or delivered to a market place in the city. The largest percentage of producers selling additional products was found to be in the Attleboro area, whereas the largest sale per producer was in Gardner area. The latter, however, was due to the fact that several producers sold most of their milk in the form of cream. (Table 3.)

TABLE 3. ANNUAL SALES OF OTHER PRODUCTS BY PRODUCER-DISTRIBUTORS OF MILK IN 1931-32

Products Sold	Attleboro		Gardner		Newburyport	
	Number Selling	Value of Sales	Number Selling	Value of Sales	Number Selling	Value of Sales
Poultry & Eggs, Vegetables, Cream	1	$1,050	—	———	1	$2,719
Poultry & Eggs, Vegetables, Misc.	1	330	—	———	—	——
Poultry & Eggs, Cream	—	———	1	$3,500	1	310
Poultry & Eggs, Vegetables	5	1,625	—	———	1	700
Vegetables only	6	1,200	—	———	1	1,200
Poultry & Eggs only	7	1,050	2	105	2	250
Cream only	4	1,840	6	5,460	3	1,102
Totals	24	7,095	9	9,065	9	6,281
Milk only	11		17		8	
Total Producer-Distributors	35		26		17	

Family and Hired Labor

One of the most important changes in farm life has been due to unemployment in the city. Considerable increase in farm population has been caused by the return to the farm home of members of the family formerly living and working in the city. On practically every farm visited, at least one such additional person was found. Among these were married children with their families, brothers, sisters, and more distant relatives or friends. As a result most of the producers were supplied with more labor than they could use. As indicated in Table 4, practically every farm had some assistance from the members of the family, either on a full- or a part-time basis. Comparatively few producer-distributors hired labor with payment of wages.

Table 4. Family and Hired Labor of Producer-Distributors in 1931-32

Number Working	Attleboro		Gardner		Newburyport	
	Number of Farms		Number of Farms		Number of Farms	
	Full Time	Part Time	Full Time	Part Time	Full Time	Part Time
			Family Labor			
1	29	17	14	7	11	5
2	2	5	8	3	2	1
3	1	1	4	2	1	—
			Hired Labor			
1	5	6	5	5	3	3
2	—	2	2	1	1	1
3	1	—	1	—	—	—
4	—	—	1	—	—	—
7	—	—	1	—	—	—

Producers in Gardner Area

The number of producers supplying milk to Gardner distributors and their total output have changed little since 1930. (Table 5.) Like producer-distributors, most of them owned small herds, less than 20 per cent having 15 cows or more.

Table 5. Average Daily Milk Production of Producers in Gardner Area

Year	Number of Producers	Quarts Produced Daily
1930	70	8,335
1931	72	7,951
1932	73	8,036

TABLE 6. DISTRIBUTION OF COWS OWNED BY PRODUCERS IN GARDNER AREA

Distribution of Cows	Number of Producers	Total Number of Cows
Below 5	10	34
5-9	33	225
10-14	17	197
15-19	9	155
20 or over	4	236
Total	73	847

(Table 6.) Most of the producers, however, had some supplementary income either from outside employment or from other farm enterprises. During the preceding year about one third did some work off the farm by which they earned a total of $8,205; 48 out of a total of 73 sold poultry and eggs to the amount of $14,285; and 58 sold vegetables and other products to the amount of $11,670. (Table 7.)

TABLE 7. ANNUAL SALES OF OTHER PRODUCTS BY MILK PRODUCERS IN GARDNER AREA, 1931-32

Products Sold	Number of Producers	Value of Sales
Poultry	40	$4,220
Eggs	48	10,065
Vegetables and other	58	11,670

The combined average daily output of milk producers and producer-distributors in Gardner area has remained at a level of about 11,000 quarts for the last three years. The average daily sales of milk in that market were nearly 7,000 quarts, leaving a surplus of 4,000 quarts. Under normal conditions this excess of milk was sold by distributors in the adjoining markets without great difficulty. For the last two years, however, the adjoining markets, especially the city of Fitchburg, have been oversupplied with milk coming from outside areas, resulting in sharply lower prices. Under these conditions the surplus milk in Gardner area became more burdensome, and the large dealers, who lost much of their business to producer-distributors, began to drop off some of their producers. A few of these in the town of Hubbardston found a new outlet in sales to a dealer from Worcester. Several others could not find an adequate market at all and planned to sell off their cows.

MILK SALES AND CONDITION OF MARKETS

Gardner

As will be seen from Table 8, the course of the sales of milk in the three markets has showed varying tendencies since 1930. Inasmuch as all three of these markets were affected by unemployment and the fall in purchasing power, the variations in demand are to be explained largely by the condition of supply, local regulations, and price policies pursued by local distributors. During the 3-year period

since 1930 the greatest competition in the sale of milk influenced by the pressure of supply took place in the Gardner market. This condition was caused on the one hand by the influx of producers into the distributing field so that the total number of distributors increased from 25 in 1930 to 33 in 1932; and on the other hand by a rapid fall in prices in the adjoining markets which caused some dealers operating in several markets to divert some of their milk into Gardner and thus add to the existing surplus of milk. Under these conditions the prices of milk began to decline in Gardner and about the middle of 1931 there ensued a real price war with much of the milk selling below 10 cents a quart, not to mention various concessions made by distributors in order to retain their customers. To prevent a complete disorganization of the market and bring about an orderly sale of milk, the distributors joined together in an organization through which they agreed among other things to maintain a retail price of 12 cents. Inasmuch, however, as the fundamental causes of competition resulting from oversupply were not removed, and milk in the neighboring markets was selling lower, the price agreement was operative only for a short period of time. At the time of the investigation the prevailing retail price was 10 cents with much of the milk selling below that figure. With the continued decline in prices and increased competition, the established dealers in Gardner, with large investments in plants and high fixed charges, were decidedly at a disadvantage.

With lower prices prevailing throughout the period, the consumption of fluid milk has increased in Gardner since 1930, and the largest expansion in sales took place in 1931 under the stimulus of low prices caused by undercutting. The increased sales of milk by dealers in that year were due to the previously mentioned regulations in regard to the sale of pasteurized milk, introduced by the Board of Health, which temporarily worked for the benefit of distributors with pasteurizing plants. By 1932, however, the producer-distributors, after complying with the law requiring the tuberculin test for their cows and effecting the necessary adjustments, came back into the market and more than regained their former position.

Attleboro

As contrasted with the Gardner market, in Attleboro there has been a drastic decline in the sales of milk since 1930. Among the factors responsible for this situation, the most important has been a high price level for milk maintained in 1931 and 1932 in the face of falling prices for other commodities. The system of price undercutting has not been practiced here to the same extent as in the other markets, with distributors agreeing not to sell their milk below 13 cents a quart retail. At the same time the enforcement of the regulations of the local Board of Health has made it difficult for new distributors to enter the market. Although the milk sold in Attleboro market has been generally of better than average quality, the fall in purchasing power and considerable unemployment have forced many consumers to curtail their purchases of the product at prevailing prices. Together with the decline in the sale of fluid milk, which has amounted to about 20 per cent since 1930, there has been an increase in the sale of canned milk, which many consumers have found more economical under existing conditions.

The smaller consumption of milk in the Attleboro area has resulted in a considerable surplus among local producers, and the market has given clear evidence

of the difficulty of maintaining the established price level. In fact, at the time of this investigation, a number of small distributors had begun to sell their milk at lower prices, especially in the southern section of the city where some of the milk came from the adjoining territory of Rhode Island. The total number of distributors in the Attleboro market at the time of the investigation was 50, of whom 15 were dealers and 35 producer-distributors. There has been no increase in the number of distributors since 1930; in fact, several small distributors have discontinued their operations during the last two years.

The relative proportion of milk sold by producer-distributors has increased slightly since 1930, although not to the same extent as in the Gardner market. The producer-distributors in these markets have been able to maintain their sales at a higher level than dealers, due largely to more frequent concessions in price granted to consumers. Being in closer personal contact with their customers, they have frequently supplied milk on credit to those whom they knew to be reliable but temporarily unable to meet their bills on account of unemployment or financial difficulties. In numerous instances, also, producer-distributors during the last two years have received payment for their milk on the basis of barter, either for commodities or more frequently for various services performed on their farms.

Table 8. Average Daily Sales of Milk by Dealers and Producer-Distributors

Year	Total Quarts Sold Daily	Dealers		Producer- Distributors	
		Quarts Sold Daily	Per Cent of Total	Quarts Sold Daily	Per Cent of Total
		Attleboro			
1930	9,698	5,775	59.5	3,923	40.5
1931	9,419	5,640	59.9	3,779	40.1
1932	7,787	4,530	58.2	3,257	41.8
		Gardner			
1930	6,213	2,725	43.9	3,488	56.1
1931	7,205	3,525	48.9	3,680	51.1
1932	6,915	2,825	40.9	4,090	59.1
		Newburyport			
1930	7,048	4,088	58.0	2,960	42.0
1931	6,678	4,063	60.8	2,615	39.2
1932	6,635	4,498	67.8	2,137	32.2

Newburyport

The total sales of milk in Newburyport market have on the whole remained stable since 1930. Although there has been a decline in the total milk moving to

consumers, it has amounted to only about 5 per cent. There has been no increase in the number of distributing agencies in the period since 1930, although a number of new applicants for licenses have tried to qualify for entering the market. Nevertheless during the last few years there have been considerable changes in the general set-up of the market which have resulted in decreased sales of local milk. For a period of years the Newburyport market has been supplied by milk from local sources, with small-scale local dealers and distributors maintaining about an even volume of business from steady customers. During the last few years, however, some of their business has been lost to dealers handling mostly outside milk. This business was gained by the dealers largely through advertising and improved methods of distribution. Some of the local producer-distributors have been slow in adapting themselves to the changing conditions of the market and have not done as much as they might to make their product more attractive to the consumer.

The conservatism of local distributors has, however, prevented price undercutting for gaining new business, in spite of the fact that there has been no organization of distributors nor any price agreement among them. The trend of retail milk prices in Newburyport has followed closely the general level of milk prices in other similar markets of the state, with the prevailing price of 10 cents per quart in the middle of 1932. However, with a decline of several hundred quarts in the average daily sales of milk since 1930, and the loss of another several hundred quarts in favor of outside milk, the local producers have maintained their regular output with a gradually narrowing market outlet for their milk. As in the other two markets, producers of fluid milk for local markets have been facing the problem of radical readjustment in their production policies, due to changing supply conditions in their previously dominant market outlets. It is becoming more and more evident that their former strategic advantage of higher fluid milk prices and no considerable surplus to contend with is rapidly vanishing under the equalizing influences of a competitive milk supply from an outside producing area. Once this fact is realized the producers for secondary markets will find it imperative to enter the established large producers' organizations to prevent the ruinous effects of an outside surplus in their markets.

Wholesale and Retail Distribution of Milk

The proportion of milk sold by distributors to restaurants, stores, and other agencies was highest in Newburyport and lowest in Attleboro, the figures being 32.4 per cent and 19.2 per cent respectively. (Table 9.) In all the markets the proportion of milk sold on a wholesale basis was greater for the dealers than for producer-distributors, the widest difference being in the Newburyport market, where several dealers sold their milk almost exclusively at wholesale. One of the reasons for the comparatively low proportion of milk sold at wholesale by the dealers in Attleboro market was that a group of chain stores operating in this market was importing its supply from outside areas independently of local distributors. Inasmuch as the wholesale prices for milk ranged from 2 to 4 cents per quart lower, the producer-distributors with a lower percentage of milk sold on a wholesale basis averaged a higher price than the dealers for their total sales of milk. Much of this differential was lost, however, in more frequent concessions from the prevailing price level in their retail trade.

TABLE 9. WHOLESALE DISTRIBUTION OF MILK DAILY IN 1932

	Number Selling	Total Quarts Sold Daily	Milk Sold at Wholesale Daily	
			Quarts	Per Cent of Total
Attleboro				
Dealers	15	4,530	895	19.7
Producer-Distributors	35	3,257	603	18.5
Total	50	7,787	1,498	19.2
Gardner				
Dealers	5	2,825	777	27.5
Producer-Distributors	17	4,090	810	19.8
Total	22	6,915	1,632	23.6
Newburyport				
Dealers	12	4,498	1,859	41.3
Producer-Distributors	17	2,137	290	13.5
Total	29	6,635	2,149	32.4

Pasteurized and Raw Milk

The proportion of pasteurized milk sold was about the same in all three markets, the highest being in Gardner (57.9 per cent of all milk sold) and the lowest in Attleboro (54.4 per cent). (Table 10.) Nevertheless, there have been some significant changes in the sale of pasteurized milk since 1930 in individual markets. While in Attleboro and Gardner the percentage of pasteurized milk sold has decreased slightly, in Newburyport there has been a considerable increase. This has been due largely to expanding sales by producer-distributors in the first two markets, and the opposite development in the other. In all three markets the major portion of the pasteurized milk has been sold by the dealers, and wherever their importance in the market has increased it has been reflected in greater sales of the pasteurized product. With the greater popularity of pasteurized milk among consumers, and recent regulations introduced by the local boards of health, it is to be expected that in the next few years there will be a considerable decline in the sale of raw milk in these markets.

Quality of Milk Sold

On the basis of the tests made by local milk inspectors, and in some cases by state milk inspectors, it has been possible to obtain figures for the butterfat test of milk sold by dealers and distributors operating in the three markets. The figures given in Table 11 are weighted averages of the monthly tests made for the twelve preceding months. In all the areas the average butterfat test was considerably higher than the minimum of 3.35 per cent required by the state regula-

tions. The butterfat test for the individual distributors ranged all the way from 3.4 per cent to 5.3 per cent, the latter being for Jersey milk sold by several distributors. In all three areas the milk sold by producer-distributors was of slightly higher butterfat test, the greatest variation being in Attleboro market. This market had also a higher butterfat test for both producer-distributors and dealers than the other two markets.

TABLE 10. DAILY SALES OF PASTEURIZED MILK, 1930-32

Year	Dealers			Producer-Distributors			Total		
	Total Quarts Sold Daily	Pasteurized Milk Sold Daily		Total Quarts Sold Daily	Pasteurized Milk Sold Daily		Total Quarts Sold Daily	Pasteurized Milk Sold Daily	
		Quarts	Per Cent of Total		Quarts	Per Cent of Total		Quarts	Per Cent of Total
Attleboro									
1930	5,775	5,300	90.4	3,923	1,125	28.7	9,698	6,345	65.4
1931	5,640	5,065	89.8	3,779	125	3.3	9,419	5,190	55.1
1932	4,530	4,135	91.3	3,257	100	3.1	7,787	4,235	54.4
Gardner									
1930	2,725	2,250	82.6	3,488	1,665	47.7	6,213	3,915	63.0
1931	3,525	3,050	86.5	3,680	1,775	48.2	7,205	4,825	67.0
1932	2,825	2,200	77.9	4,090	1,800	44.0	6,915	4,000	57.9
Newburyport									
1930	4,088	2,288	56.0	2,960	180	6.1	7,048	2,468	35.0
1931	4,063	3,103	76.4	2,615	150	5.7	6,678	3,253	48.7
1932	4,498	3,583	79.7	2,137	40	1.9	6,635	3,623	54.6

Figures on the total solids in milk were available only for the Attleboro and Gardner markets. Computed on the basis of weighted averages the total solids in milk as presented in Table 11 indicate a higher average for the product sold by producer-distributors. As with the butterfat content, the Attleboro milk leads also in the content of total solids, testing on the average 12.96 per cent.

TABLE 11. WEIGHTED AVERAGE BUTTERFAT AND TOTAL SOLIDS IN MILK SOLD, 1931-32

	Attleboro		Gardner		Newburyport
	Butterfat Per Cent	Total Solids Per Cent	Butterfat Per Cent	Total Solids Per Cent	Butterfat Per Cent
Dealers	3.9	12.78	3.76	12.37	3.68
Producer-Distributors	4.3	13.25	3.97	12.65	3.81
Average for All	4.12	12.96	3.89	12.49	3.72

PRICE PLANS AND PRICES PAID TO PRODUCERS

Price plans and prices paid to producers in all three areas were characterized by the lack of uniformity ordinarily found in this type of market, and varied from one dealer to another. In general the producers selling their milk to producer-distributors or small dealers were more favorably placed with regard to the average price received for their milk. (Table 12.) In addition, most of them were situated very near to the distributing plants, often living on neighboring farms, thus making the cost of delivery of negligible importance. In many cases small distributors paid the same price for milk which they collected from the producer as for that purchased from others who delivered it to the plant. Very often it was a case of personal neighborly adjustment. The bulk of the milk was purchased by large dealers and small distributors on the basis of a flat price without discrimination as to surplus or butterfat content. Before 1932 the producers with uneven production or with milk of low butterfat content were thus placed on an equal basis with producers supplying a higher quality product and having even production. However, with more unfavorable conditions of the milk markets in 1932, and smaller purchases by dealers, curtailment took place in the form of a dropping off of the less desirable producers.

Table 12. Prices Received by Producers for Milk Sold to Dealers in All Areas in 1932

Cents per Quart	Quarts Sold Daily	Per Cent of Total
3¾	5,269	35.6
4	56	.4
4½	461	3.1
4¾	302	2.0
5	3,643	24.6
5¼	835	5.6
6	2,240	15.1
6½	1,435	9.7
6¾	480	3.2
7½	100	.7
Total	14,821	100.0

Weighted average price 4.9 cents.

In the Gardner market only one dealer purchased his milk on the basis of quality and surplus, adopting a modified price plan of the New England Milk Producers' Association. The return to the producers on this basis averaged about 3¾ cents a quart. This price was equivalent to that paid by another large dealer purchasing his milk in this area at a flat price. The rest of the dealers and producers in this area paid 5 cents a quart without differentiation as to quality. In some cases the entire output of the producer was taken and in others only a definite amount.

In agreement with the higher price for milk in the Attleboro market, the average prices paid to producers in this area were considerably higher than in either Gardner or Newburyport. There was again no uniformity either in the price

plans or prices paid to producers. The majority of them received for their milk a flat price of 6 cents per quart. Only two local dealers purchased their milk on the basis of butterfat test paying from 6 to 7½ cents per quart depending on quality, with an average of 6½ cents per quart.

The prices paid to producers in the Newburyport market presented a more uniform picture than in the other two markets. Of the total of 70 producers supplying local dealers and distributors, 60 obtained a flat price of 5 cents per quart, while the prices for the rest ranged up to 6 cents per quart. Except in the cases of two distributors who took only a definite amount through the year, leaving the care of the seasonal surplus to the producers, the arrangement was one of mutual adjustment, where producers, being mostly close neighbors, tried to keep their production within the current requirements of their distributor, and the latter in his turn often accommodated his producers by taking a greater amount of milk than he actually needed.

From the standpoint of a small market the general structure of distribution in Newburyport with the predominance of small dealers and distributors, each obtaining his milk from several producers mostly his neighbors, seems to be the most advantageous both in the way of market stability and better prices paid to producers. This system has been working fairly well in this market until recent years, and its partial collapse has been due largely to the advent of outside milk. However, if the pressure of surplus milk from other areas continues and the producers in local markets are going to lose the advantage of their strategic position, the best policy for them would be to join the existing organizations of producers and adapt themselves to new competitive conditions as they develop in their markets.

Producer-Distributors and Cost of Milk Distribution

The tendency of many producers to establish themselves in the distributing field during the last few years makes it essential to consider the advantages obtained by direct sale of their product to the consumer. Accordingly, the costs of distributing milk were obtained from 57 producer-distributors operating in the three markets. Under normal conditions the question of the cost of labor and time involved in distributing milk as compared with sale to a dealer is one of the most important factors to be considered by producers. However, as demonstrated by the figures obtained on farm family labor, in the last few years a number of people employed in the city have returned to the farms of their parents or relatives to stay during the period of unemployment. Likewise many of the producers were found to be farming on a part-time basis, gaining part of their income from factory or other employment. After losing their outside jobs, thereby gaining more time for farming operations, those engaged in dairying in some cases increased the size of their herds. This, however, was not always possible either because of the inadequacy of the farm, the lack of additional funds, or, most often, the difficulty of finding a profitable market for an increased output of milk. Under these conditions, among producers situated conveniently near the markets there was a natural tendency to enter the distributing field, provided they had the necessary equipment and the possibility of obtaining something over and above the additional cash expenses incurred for the purpose.

The cost of labor was of slight consideration as long as the time spent in distribution did not offer any alternative employment. Another important factor inducing producers to distribute their milk was the widening margin between the price paid to producers for their milk and that prevailing in retail distribution.

Distance from the Market and Miles Traveled

Most of the producers found in the distributing field were located in close proximity to the market. As will be seen from Table 13, of the 57 producer-distributors whose costs of distribution were covered by this study, almost two-thirds were located within four miles of the center of the market in which their milk was sold. Only a little over one-fourth of the producer-distributors lived more than six miles from the market.

Table 13. Distance from Market of 57 Producer-Distributors in Attleboro, Gardner, and Newburyport

Miles	Number of Producer-Distributors	Per Cent of Total
Below 2	14	24.6
2-3.9	22	38.6
4-5.9	6	10.5
6 or over	15	26.3
Total	57	100.0

With the exception of a few distributors who sold their milk in more or less compact districts, there was present in these markets the familiar duplication of routes, and travel over considerable distances to supply a few customers. Only a little over one-third of the distributors covered a total distance of less than 10 miles in the distribution of milk over one route. (Table 14.) The majority of distributors used small trucks; automobiles were used by a few small retailers; and there were several horse-drawn vehicles.

Table 14. Miles Traveled Daily on Milk Routes by 57 Producer-Distributors in Attleboro, Gardner, and Newburyport in 1932

Miles	Number of Producer-Distributors	Per Cent of Total
Below 10	20	35.1
10-14	18	31.6
15-19	13	22.8
20 or over	6	10.5
Total	57	100.0

Cost of Distribution

In the case of most of the distributors it was extremely difficult to determine the exact cost of using trucks or other vehicles for the distribution of milk. No accurate accounts were kept, and the vehicles were used for other business and family needs. For the purpose of this study, the cost of running a truck or automobile was assumed to be 6 cents a mile, inasmuch as this figure was most frequently mentioned by the distributors. (See also Bulletin 272 of the New Hampshire Experiment Station.)

The regulations in all three markets required every distributor to have a special milk room, built according to certain specifications, for the handling of milk prior to distribution. These rules, however, could not be enforced very strictly in the case of many small distributors who, complying on the whole with the necessary safeguards in the handling of milk, often had very rudimentary provisions for this purpose. Mainly for this reason the cost of depreciation and interest on investment per quart of milk for small distributors was lower than for those handling 200 quarts or over. The latter group ordinarily had more expensive equipment and, in several cases, pasteurizing plants. Neither were the small distributors at a disadvantage in their average current expenditures, including the cost of bottles, caps, ice, advertising, and other items involved in selling milk direct to the consumer. The higher cost of handling milk by small distributors was caused by the expense of delivery, where a partially loaded truck was used to carry milk over an extended route. The highest cost of delivery was found among those handling under 50 quarts and the lowest in the group selling between 150 and 199 quarts. A slight increase in the cost of delivery per quart was found in the group selling over 200 quarts, largely because the amount of milk handled in some cases involved the use of two vehicles, not fully loaded.

Milk Prices, Cost of Distribution and Producer-Distributors

For 57 producer-distributors whose cost records were obtained in the three areas, the average cost of distribution was 1.3 cents per quart, not including the cost of labor. (Table 15.) Except for a few large producer-distributors, the milk business of these operators was carried on without any hired labor; and in their decision to enter the distributing business the main consideration was the differential between the price paid by the dealers and that obtained in the retail trade. The average price paid to the producers in the Gardner market was 4.1 cents; in Attleboro, 6 cents; and in Newburyport, 4.8 cents. If to these alternative prices are added the average expenses involved in distribution, the total cost of milk to the distributor would be 5.4 cents in the Gardner market, 7.3 cents in Attleboro, and 6.1 cents in Newburyport as compared with much higher prevailing retail prices in these markets.

In all these markets, therefore, and especially in Gardner, there was considerable inducement for producers not dependent on hired labor to enter the distributing business and to obtain customers even by making a reduction in the retail price. It is not to be assumed, however, that every producer is in a position to begin the retailing of milk exclusively on the basis of the advantage in price and availability of the necessary labor. There are many limiting factors both from the standpoint of adequate equipment and ability to sell milk at retail in

a highly competitive market. Nevertheless a number of producers consider themselves qualified for the undertaking, as is demonstrated by the number of applications for distributing licenses filed with the milk inspectors in the past two years in all three markets.

TABLE 15. COST OF MILK DISTRIBUTION PER QUART, EXCLUSIVE OF LABOR, FOR 57 PRODUCER-DISTRIBUTORS IN 1931-32

Quarts Distributed Daily	Number of Producer-Distributors	Total Quarts Distributed Daily	Cost of Distribution per Quart			
			Interest and Depreciation	Current Expenses	Delivery	Total
Below 50	11	321	$0.0013	$0.0037	$0.0204	$0.0254
50- 99	21	1,475	.0015	.0051	.0095	.0162
100-149	11	1,305	.0013	.0045	.0063	.0121
150-199	4	685	.0013	.0038	.0047	.0098
200 or over	10	2,745	.0020	.0040	.0050	.0109
Total or average	57	6,531	.0016	.0042	.0071	.0130

SUMMARY AND CONCLUSIONS

1. With modern facilities in transportation and increased competition from outside areas, the secondary milk markets in Massachusetts are no longer able to maintain their independence from the conditions in the larger markets of the state.

2. In a period of business depression and prevailing unemployment, the disorganization of small milk markets results both from the tendency of more producers to enter the distribution field and from the pressure of outside milk.

3. An attempt to maintain a stable price level independently of the general market trend or to limit the influx of outside milk by restrictions is not likely to be successful, as it results either in the curtailment of sales of milk as in Attleboro, or in the shifting of an additional supply of milk to the local market by distributors operating in several markets, as in Gardner.

4. The average net price obtained by producers for their milk in the summer of 1932 was 4.1 cents a quart in Gardner area, 6 cents in Attleboro, and 4.8 cents in Newburyport. The highest percentage spread between these prices and prevailing retail prices was in Gardner and the lowest in Newburyport.

5. Not including labor, the average cost of distributing milk for producer-distributors was 1.3 cents a quart.

6. While under normal conditions the small producers would have found it unprofitable to distribute their milk, the excess of labor on the farms, the lack of other income, and the low milk prices during recent years have made it attractive to a good many of them to get some return for their product over what they would have been paid by the dealer.

7. For the maintenance of stability in a small market during the period of depression it is a good policy for local dealers to bring the margin of spread between the retail price of milk and that paid to producers to a point which will prevent too many producers from crowding into the distributing field.

8. The milk marketing set-up prevailing in Newburyport, where most of the producers sell their milk to small dealers and distributors, largely their neighbors, was found to be the most economical type of marketing machinery for a secondary market. The advantages under this set-up are: (1) lower cost of delivery to distributor; (2) better adjustment of production to eliminate seasonal surplus; (3) higher prices received by producers.

9. Inasmuch as, with the constantly increasing competition from outside areas, the advantages in price received by milk producers supplying secondary markets are rapidly disappearing, it is advisable for local producers to join the producers' organizations to secure better bargaining power and establish uniform price plans.

10. The price plans adopted for secondary markets should be adequate for local producers to secure for the communities the necessary supply of milk throughout the year.

Publication of this Document Approved by Commission on Administration and Finance
4M-1-'34. No. 304.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 305 MARCH 1934

Annual Report

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION — 1933

INTRODUCTION

F. J. Sievers, Director

In the field of research the merit of the product will always be directly proportionate to the ability of the investigator. For this reason, if no other, standardization should never be carried to a point where it interferes with the opportunity for the worker to express his individuality. With emphasis on this point, nothing can influence an experiment station organization quite as much as a change in personnel. During the last year this Station has seen pronounced changes in this respect.

On December 26, 1932, Dr. Joseph B. Lindsey, at the age of 70, was automatically retired from service through the operation of the retirement system for employees of the Commonwealth. He had been identified with the College for about forty years of continuous service in various capacities: as Assistant to Dr. Charles A. Goessmann, the first Professor of Chemistry at the College and the founder of the Experiment Station; as Research Professor in Animal Nutrition, a position held until his retirement; as Goessmann Professor and Head of the Department of Chemistry; and as Vice Director of the Experiment Station.

During this period he was not only a pioneer in the research related to animal nutrition, but also a very prominent factor in directing and formulating legislation which protected the farmer against adulterated feeds and fertilizers. His interest in most phases of education and his distinct common sense and practical approach to all problems, coupled with a strong and lovable personality, made him a delightful leader. Among agricultural scientists he is best known for his contributions in the field of animal nutrition, but his friends place a much greater value on his qualities of manhood.

A much more tragic change in the Experiment Station organization was experienced on December 5, 1933, through the sudden death at the age of 61 of Dr. Roscoe W. Thatcher. His record in the field of education is well known and since his death has been so thoroughly reviewed in scientific journals and local publications that it requires no consideration here further than to say that he had been given every honor that his associates had it in their power to bestow.

He accepted the presidency of Massachusetts State College in 1927 and served in that capacity until 1932, when he found it necessary to retire because of poor health. This decision made him free to accept appointment as Research Professor of Chemistry in the Experiment Station. After a leave of absence of several months, he actively and enthusiastically entered the field of research where every one hoped he would give many more years of valuable service. His sane viewpoint, conscientiousness in effort, and splendid training justified this expectation. His honesty and fairness combined with a frankness and sincerity all too uncommon made him beloved and respected by all with whom he made contact. He was not unwilling to confess his own faults and was so charitable to the faults of others that it was a pleasure to work with him. His leadership in education and especially in the organization and direction of research has made a lasting impression. His friendship and lovable character we shall never forget.

DEPARTMENT OF AGRICULTURAL ECONOMICS

Alexander E. Cance in Charge

Factors Affecting the Price of Eggs. (A. H. Lindsey.) Work on this project was suspended to allow for the completion of the bulletin on "Shipping Massachusetts Apples," in time for publication this fall.

Competitive Factors Influencing the Supply of Market Milk and Cream. (A. H. Lindsey and A. E. Cance.) The importance of the secondary markets to the dairymen of Massachusetts is illustrated by the fact that 81.6 per cent of the supply to 29 Massachusetts cities of over 10,000 people (outside of the Metropolitan milk shed) came from within the State. Vermont supplies 7.1 per cent; New Hampshire 5.3 per cent; Connecticut 1.9 per cent; Rhode Island 3 per cent New York 1 per cent; and Maine 0.07 per cent. These out-of-state supplies total 41,667,305 quarts yearly. This may be compared with 65,420,000 quarts supplied to the Boston area by Massachusetts producers.

Data on the consumption of milk by 5,010 to 7,793 families in Worcester during the month of April for the years 1928, 1930 and 1932 were supplemented by data for 8,032 families for April 1933. Data for about 400 identical families for the same periods were also obtained. In summary the data show that the average regular daily deliveries of milk per family were:

Quarts	Year	Index
1.366	1928	100
1.351	1930	99
1.362	1932	99
1.317	1933	96

That is, regular deliveries in 1933 were about 96 per cent of those in 1928.

The data on the consumption by identical families are subject to slight error because of the disappearance in 1932 and 1933 of some of those selected in 1928. Using an index of 100 to represent average daily consumption in April 1928, the index rose to 101 in 1930 and then fell to 98 in 1932, and to 91 in 1933.

In general the data indicate a comparatively stable demand for milk despite lowered incomes and unemployment.

Marketing of Milk in Secondary Markets of Massachusetts. (David Rozman.) This study has been completed and published as Bulletin 304.

Decentralization of Industry and Part-Time Farming in Massachusetts. (David Rozman.) This project has been approved only recently, and the work is in its initial stages. The main objectives are to investigate and analyze the most important features connected with part-time farming made possible by the location of industrial plants in small towns and villages, and to indicate the type and condition of land settlement most suitable under varying conditions of working in the industrial plants established in the country.

Changing Methods of Wholesale Distribution of Perishables. (Lorian P. Jefferson.) The importance of this project increases as the emphasis continues to shift from one type of wholesaler to another. The traveling jobber becomes a greater factor in the system, a factor which disturbs not only the regular wholesaler and jobber but the railroads, which are affected by him as well as by the truck operator who does not hold title to the goods he carries. City and state throughout the country seek legislation looking to the control of both these

agencies. With these changes there is also some evidence of change in credit arrangements.

Shipping Massachusetts Apples. (A. H. Lindsey and A. A. Brown.) The report of this project is contained in Bulletin 299. Its publication proved very timely, for prices in the Boston market this year are much lower than prices in other large eastern markets, and consequently producers have found it profitable to ship to markets suggested in the bulletin.

DEPARTMENT OF AGRICULTURAL ENGINEERING

C. I. Gunness in Charge

Investigation of Apple Storages. (C. I. Gunness.) The study of the effect of humidity on evaporation from apples in cold storage has been continued, and results to date indicate that the humidity should not be allowed to fall below 80 per cent in order to prevent shriveling. The work on holding the apples at a temperature higher than 32° for the early part of the season has been continued, and results are reported by the Department of Pomology. No appreciable difference in humidity has been obtained from the use of wet and dry blowers in the one storage where both types are used under similar conditions.

Apple Handling Equipment. (C. I. Gunness.) A pivot tray type of elevator has been developed for handling apple boxes, and plans prepared for distribution. This type of elevator has proved very satisfactory, and particularly economical in floor space as compared with escalators.

A washer for the removal of spray residue on apples has just been completed for experimental work to be carried on in the Department of Pomology. The outstanding feature of this washer is that the acid tank is placed near the floor with the washing tank above it. Apples are moved by a spray from a circulating pump, and the apples are raised from the acid bath, taken through the wash bath, and delivered to the grader by means of a tray elevator.

Fertilizer Distributors. (C. I. Gunness.) The fertilizer attachment which was developed last year for a tobacco transplanter was further improved during the past season, particularly by providing stirring equipment in the hopper to prevent arching. The results obtained through the use of this attachment are reported by the Department of Agronomy.

Milk Cooling Equipment. (C. I. Gunness.) During the past year a device was developed for pre-cooling milk in 20- or 40- quart cans during the time of milking by directing a spray of water on to the outside of the can. It was found that milk can be pre-cooled to 70° with a reasonable amount of water with cooling water at 55° or less.

In order to overcome the difficulty of low water in milk cooling tanks where part of the milk is cooled in the evening and part in the morning, an arrangement was developed whereby a circulating pump forced a spray of water directly on to the neck of the can where the water did not come up to the level of the milk in the can. With this arrangement it was found that milk could be cooled from 90° to 50° in 45 minutes.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Pasture Experiments. (A. B. Beaumont.) Results of experiments in the top-dressing of upland permanent pastures in Worcester County for three years (1930, 1931, 1932) have been summarized. A marked response to applied nitrogen, medium response to potash and lime, and a slight increase due to superphosphate are shown. A chemical study of the soils showed that they were deficient in readily "available" phosphorus but had a high fixing capacity for phosphoric acid.

Longevity of Alfalfa Stands. (A. B. Beaumont.) In 1927 ten varieties and strains of alfalfa were sown with differential fertilizer and lime applications. Marked differences were found in longevity of varieties and strains, but practically no differences which could be assigned to fertilizer or lime treatments. The experiment proved that varietal adaptation to climatic conditions was a much more important factor in the longevity of alfalfa than induced soil fertility conditions.

The first phase of the experiment was concluded in 1930, and the field was plowed and fallowed until the summer of 1931 when it was refertilized and reseeded with one variety of alfalfa (Grimm). Greater differences in amounts of applied fertilizer were made at this time than at the beginning of the experiment. Yields of the second cutting of the 1932 and 1933 crops were weighed and indicate a slight response to phosphoric acid and potash. The stand is still good on all plots except those which received no fertilizer. The experiment must be continued longer before conclusions can be drawn.

Legume Variety Tests. (M. C. Darnell and A. B. Beaumont, in cooperation with the Eastern States Farmers' Exchange and the Division of Forage Crops and Diseases, Bureau of Plant Industry, U. S. D. A.)

Alfalfa. The highest yielding varieties for 1933 were as follows:

1929 seeding (from second cutting only): Italian (1.82 tons); Utah (1.74 tons); Dakota, Kansas and New Mexico (1.71 tons).

1930 seeding (from two cuttings): South African (3.72 tons), Hungarian (3.70 tons), Italian (3.65 tons), Oklahoma (3.57 tons), and Hardigan (3.51 tons).

1931 seeding (from two cuttings): New Mexico 19010 (4.63 tons), Hardigan (4.56 tons), New Mexico 19011 (4.54 tons), Argentine (4.53 tons), and Utah (4.49 tons).

1932 seeding (from two cuttings): Cossack (3.26 tons); Hardigan (3.03 tons); New Mexico (2.96 tons); Grimm (2.80 tons); Ontario Variegated, Kansas, and Montana (2.77 tons).

No new alfalfa plots were seeded in 1933.

Red Clover. The data from two cuttings of red clover plots seeded in 1932 afford the same conclusions as in previous years—that the northern-grown American varieties are the best yielders. The highest yielder was Ohio (3.78 tons). No new plots were seeded in 1933.

Vetch. The results of the 1932 fall seeding of vetch and wheat were incorporated in a summary of vetch yields covering the duration of the experiments, 1930–1933. From the 1932 seeding, Oregon Hairy yielded .79 tons of vetch, followed by Smooth which yielded .69 tons. For the two years, the Smooth vetch averaged .70 tons, Oregon Hairy .69 tons. It was concluded that this

legume should not be permanently substituted as a forage crop for clovers, alfalfa, or soybeans.

Soybeans. Forty-nine new soybeans, including nine edible varieties, were observed in 8-foot rows, to determine their adaptability to New England conditions. Two of the edible varieties and seven of the forage varieties did not reach maturity.

Sweet Clover. Plots of hulled and unhulled sweet clover were seeded at intervals from December 1931 to May 1932, and their yields compared after cutting in 1933. The best yield (2.19 tons) was obtained from the February 1 seeding of unhulled. This is in general agreement with the results of the previous experiment.

Crimson Clover. The highest yields of crimson clover (.96 tons when grown with oats as a companion crop, 1.19 tons when grown alone) were obtained from plots seeded in the middle of May rather than later.

Lespedeza. Two strains of early Korean Lespedeza were seeded early in May, and the seed harvested in October. Strain 65280 yielded 72 pounds of seed per acre; strain 59379, 101 pounds per acre. A rather dense growth was observed on the volunteer reseeding from the shattered seed of the previous year's crop.

These two strains were also seeded on an upland pasture early in the spring before frost had come out of the ground. Seed were not worked into the soil by artificial means. The fields used had been previously used for a top-dressing fertilizer and lime experiment. There was a fair stand of lespedeza plants early in the spring before grazing had begun, but at the end of the season less than 1 per cent of lespedeza plants could be found in the sod. They were very small, but in most cases bore seed. Little or no difference in stand of lespedeza could be attributed to the differential fertilizer and lime treatments.

Top-Dressing Grasslands with Fertilizers. (A. B. Beaumont, R. W. Donaldson, and M. E. Snell.)

Fertilizer Ratios. Part I of this experiment was terminated at the close of the 1932 season, and the field plowed and reseeded in the summer of 1933. The general plan of the previous experiment was followed except that enough phosphoric acid (in the form of 16 per cent superphosphate) to last for about 5 years was applied and harrowed in prior to seeding. Nitrogen and potash will be applied annually as top-dressing. Part II was started in 1932, and differs from Part I only in that wider ratios were used. The yields are summarized below:

Mean Yields of Cured Hay

Part I, 5 years (1928-1932)			Part II, 2 years (1932-1933)		
Fertilizer Ratio	Pounds per Acre	Rank	Fertilizer Ratio	Pounds per Acre	Rank
6:3:3	5171	1	8:3:3	4785	1
4:3:3	4533	8	4:3:3	4002	7
2:3:3	3985	9	0:3:3	2778	9
3:6:3	4811	5	3:8:3	4320	4
3:4:3	4691	6	3:4:3	4055	6
3:2:3	4831	4	3:0:3	4107	5
3:3:6	5162	2	3:3:8	4565	2
3:3:4	4858	3	3:3:4	4433	3
3:3:2	4571	7	3:3:0	3544	8

It may be noted that a distinct response to nitrogen and potash, but no response to phosphoric acid, all as top-dressing, is indicated by these figures.

Forms of Nitrogen. This experiment in the top-dressing of an old mowing was started in 1932. Cyanamid came from last place last year to first place this year in the order of effectiveness. The relative yields from the various treatments for 1933 are as follows:

Check (no nitrogen)	100
Ammonium Sulfate	192
Urea	193
Nitrate of Soda	216
Cyanamid	220

This field has received no phosphatic or potassic fertilizers and no lime since the experiment began.

Experiments with the Newer Nitrogen Fertilizers. (A. B. Beaumont.) In the spring of 1929 a field experiment was started with several of the new nitrogen fertilizers, some of the old standard carriers being used for comparison. The materials used were:

	Per cent N	Per cent P_2O_5
Ammonium Sulfate (by-product)	20.5	
Ammonium Phosphate (Ammo-Phos)	11	48
Diammonium Phosphate (Di-ammonphos)	21	53.4
Ammonium Chloride	26.2	
Calcium Nitrate	15.5	
Nitrate of Soda (Chilean)	15.5	
Nitrate of Soda (synthetic)	16.25	
Urea	46	
Calcium Cyanamid	22	

For the first two years of the experiment, the fertilizer used on all plots was equivalent to 800 pounds of a mixture containing 4 per cent N, 17.45 per cent P_2O_5, and 6 per cent K_2O. No fertilizer was applied the third year when hay was grown. The fourth and fifth years the fertilizer was equivalent to 1200 pounds of the mixture indicated. The reaction of the soil used was about pH 6.2 at the beginning of the experiment. Four crops of ear corn and one crop of mixed grass and clover hay have been grown in the period 1929-1933. No significant differences in yield have been obtained from the different fertilizers, although the yield from ammonium sulfate is trending low. This material and ammonium chloride have slightly lowered the pH value of the soil. The nitrates and calcium cyanamid, particularly the latter, have somewhat raised the pH value. The two ammonium phosphates and urea have not effected marked differences in the soil reaction.

This experiment indicates that on a soil of this character one may expect almost identical results from the nitrogen fertilizers used for tilled crops having requirements similar to those of corn for a period of five years at least, without the use of lime. If the experiment is to be continued on the same plan, further divergence in soil conditions resulting from the use of the different nitrogen fertilizers, and corresponding variations in yield of crops may be expected.

Field Experiments with Tobacco. (A. B. Beaumont and M. E. Snell.)

Cropping Systems. Results for the period 1924-1932 were summarized in the last annual report and have since been published in Bulletin 297.

In 1933 changes were made in the plan of the experiment which involved the lengthening of the tobacco rotation and the substitution of new cover crops for some which had been tried several years. As no lime had been applied to the field since the beginning of the experiment, and the reaction of the soil had been reduced to a fairly low point (about pH 5.0), all plots except five of the check plots were given an application of limestone at the rate of 1 ton per acre in the spring of 1933. (It should be understood that the differential treatments listed were supplementary to fertilizer which was applied to all plots alike.) Yields from the various treatments were:

	Pounds per Acre
Check plots without lime	1894
Check plots with lime	1809
Manure supplement	2017
Manure and red top cover crop	1747
Oats cover crop	1742
Barley cover crop	1557
Spring wheat cover crop (sown in the fall)	1545
Clover cover crop	1766

Form Of Nitrogen. In the experiment with fertilizers having one half of the nitrogen from cottonseed meal and the other half from different carriers, the highest yield was obtained from the mixture containing calcium cyanamid, closely followed by the standard mixture (containing a mixture of different nitrogenous materials), urea, nitrate of soda, and ammonium sulfate.

Quantity of Organic Nitrogen. In the experiment with different proportions of organic and inorganic nitrogen, the highest yield was obtained from the mixture containing 3/8 organic nitrogen and 5/8 inorganic nitrogen, while that containing ¼ organic nitrogen gave the lowest yield. Tobacco grown in this experiment in 1932 showed little difference in grade index when sorted.

Method of Applying Fertilizer to Tobacco. This experiment was continued in 1933 with the same methods and equipment that were used the previous year. The average yields were as follows:

Machine Application	Pounds per Acre	*Broadcast Application (Check)*	Pounds per Acre
4/8 Standard application	1782	Standard application	1900
5/8 Standard application	1778	Standard application	1801
6/8 Standard application	1885	Standard application	1852

The experiment was repeated on one of the nearby private farms used in 1932. The highest yield was obtained with the 6/8 standard application alongside the row.

Four years' results from this experiment indicate that the amount of fertilizer may be reduced 1/4 to 3/8 without reducing yield or impairing grading quality of tobacco, if the fertilizer is applied near the row instead of broadcast. In addition, the operations of broadcasting and harrowing in fertilizer are saved.

Magnesium Requirement of Crops. (A. B. Beaumont and M. E. Snell.) The soil on which this experiment is being conducted is only moderately deficient in magnesium, judging from reports of experiments on magnesium-deficient soils in other sections. Within recent years 14 common crop plants have been grown in this experiment, but only 5—corn, tobacco, oats, buckwheat, and turnips—have shown definite symptoms of magnesium deficiency, and the yield of some of these was not seriously reduced. Buckwheat is one of the most sensitive to magnesium deficiency of the plants studied in this experiment. Certain weeds have shown marked symptoms of magnesium deficiency. The crops grown in 1933 were barley, oats, Sudan grass, Japanese millet, buckwheat, turnips, and corn. With the hope of accentuating soil differences of the field under experiment, an acid-producing fertilizer was used this year, and another application of lime was given the portion previously limed.

Methods for Determining Magnesium Deficiency in Soils. (J. L. Haddock.) Various laboratory methods for the determination of mineral deficiencies in soils were studied during 1931-32. Two of these methods showed fair agreement with pot and field tests. The Newbauer method may be used on soils very deficient or well supplied in magnesium. The exchangeable magnesium as obtained by soil extraction with normal KCl solution gave close agreement with magnesium-deficient soils, as shown by chlorosis of corn and tobacco.

An interesting observation was made in the summer of 1932 on the magnesium plots. It was noted that the common weed, lamb's quarters (*Chenopodium album* L.), was growing on all plots along with buckwheat. On the plots treated with magnesium the weeds grew to an average height of 3 feet, while on the deficient plots there were fewer weeds and the plants had an average height of only 15 inches.

Chemical analysis of corn and lamb's quarters grown on the magnesium plots gave some interesting results which suggest that this weed may be useful as a magnesium indicator plant.

Chemical Content of Corn and Lamb's Quarters as Influenced by Soil Treatment

Treatment	Content of Corn Stover Per Cent		Content of Lamb's Quarters Per Cent	
	Ca	Mg	Ca	Mg
Calcium alone	0.49	0.12	2.39	0.16
Calcium+magnesium	0.39	0.15	1.98	0.44
Magnesium alone	0.38	0.18	1.40	0.48
No calcium; no magnesium	0.41	0.08	1.67	0.12

Onion Field Experiments. (M. E. Snell.)

Onion Set Production. The past season's work on this project has but confirmed the statements made in the last annual report regarding fertilization for onion set production. The yields of sets were somewhat lower in 1933, and there was a tendency for the smaller sizes to be slightly more numerous. Since the use of 500 pounds of the 2-12-8 fertilizer was so successful last year, 1000 pounds were tried this year, but no improvement was seen. In previous tests all rows have been 13.8 inches apart, but the past season they were tried 8 and 11 inches apart. It was rather difficult to operate between rows only 8 inches apart, and the yield was not increased with the 500 pounds of 2-12-8 fertilizer used. Perhaps 1000 pounds of this fertilizer would have been better in this case.

The 11-inch rows, however, gave very good results with the same fertilizer application.

The sets produced in 1932 were graded and weighed for storage loss after they had been stored for about six months. The loss included sprouting, decay, and shrinkage from loss of moisture. On the ½-¾ inch sizes, the loss was 28 per cent with the sets grown on the 0-12-8 fertilizer as compared with about 15 per cent on the other fertilizer treatments. The losses of the sets grown with 500 pounds of the 4-12-8 fertilizer were as follows:

Size of Set	Loss Per Cent
¼-½ inch	20
½-¾ inch	16
Over ¾ inch	13

Since the ultimate value of onion sets is for the production of onions, a test was made to determine the influence of the fertilizer treatment used in growing the sets on the yield of plants grown from these sets and their tendency to develop seed stalks and multiple bulbs. The sets grown in these tests were also compared with commercially grown sets. Both of the two larger sizes were planted because the smaller size would not give information on seed stalk production. The large size, ¾–1 inch, gave a considerably higher total yield, but after the removal of all bulbs which developed seed stalks or multiple bulbs, the difference was very slight. With the small size sets, multiple bulbs were negligible in all cases, and less than 1 per cent had seed stalks except for the commercial which had 3.8 per cent. The large size, ¾–1 inch, gave the following results:

Sets	Fertilizer Used to Grow Sets	Percentage with Seed Stalks	Percentage with Multiple Bulbs
¾–1 inch	0–12–8	15.7	3.1
	2–12–8	18.2	3.6
	4–12–8 (500 lbs.)	18.7	2.1
	4–12–8 (1000 lbs.)	28.3	8.5
Commercial sets		37.9	17.7

This seems to indicate not only that good yields of the desired size of set can be produced locally, but that they compare very favorably with commercial sets for keeping quality and production of onions. It must be remembered, however, that this test is only for one year, and the results may not be conclusive.

Onion Transplants. During 1933 another attempt was made to study the possibilities of growing onions from transplants instead of from seed or sets. This phase of onion growing is being considered because of the difficulty of growing good crops of seed onions and the expense of planting set onions, as well as the possibility of growing some of the larger, milder types of onions in this section.

It takes about three months in a greenhouse to grow plants for transplanting, and the labor of transplanting is about the same as it is with sets; so the expense of planting is pretty high.

In the trials made, seed onions which were planted at the same time as the transplants were not at all promising, but very fair results were obtained with the transplants of some of the varieties. Transplants would generally yield less than sets and would be later maturing, but very good yields of high grade onions can be obtained by this method.

Onion Breeding. (M. E. Snell.) The past season some of the better yielding inbred strains were planted on fair-sized plots for comparison with some of the better commercial varieties grown locally. Since the season was very unfavorable for seed onion production, the yields were very small and poor in all cases, but the commercial varieties were generally superior to the inbred strains.

For the first time bulbs selected from first-generation hybrids were planted for seed production. Many of the bulbs showed good vigor as compared with the inbred strains. Sets had also been grown from inbred strains and were planted for bulb production. The growing plants from the sets were remarkably uniform in type and in most cases had some outstanding characteristics. This phase of the breeding work should not be overlooked, as it appears that the principal way in which onions are to be grown in this section is from sets. Sets also offer much more satisfactory material for this work than seed onions which often give very unsatisfactory yields necessitating the use of undersized and poor bulbs for seed production. With sets there is, of course, the difficulty of growing good sets for planting from only a small amount of seed

The past season the bulbs for crossing were grown in the station glasshouse on cars which could be pushed in or out as desired. This permitted the pollination of flowers in wet weather as well as fair, and a much better set of seed was obtained than previously.

Toxicity of Aluminum for Tobacco. (Walter S. Eisenmenger.) Tobacco plants were grown in aluminum citrate solutions. These plants grew in a complete nutrient solution for two days, and on the succeeding two days the phosphates were withheld and various concentrations of the aluminum salt were added—0, 2, 5, 15, 30, 50, 70, 85, 95, 98, and 100 per cent of 0.006 M. Toxicity was indicated in dry weight of tops and roots.

At present the antagonistic effect of the calcium ion on the aluminum ion in the nutrient solution is being determined.

The Toxicity of Aluminum for Seedlings, and the Action of Certain Ions in the Elimination of the Toxic Effects. (Walter S. Eisenmenger.) Seedings of corn, soybeans, and buckwheat were grown in various concentrations of aluminum citrate and aluminum tartrate. The concentrations were 2, 5, 15, 30, 50, 70, 85, 95, 98, and 100 per cent of 0.006 M of the aluminum salt. Fifty seedlings were used for each concentration, 50 were grown in distilled water, and 200 were grown in a complete nutrient solution. The comparison of those grown in a complete nutrient solution with those grown in the aluminum salt solution indicated that the toxicity of the salts increased with increased concentration, but the degree of toxicity was much less pronounced above 30 per cent of 0.006 M.

Both the hydroxyl and the calcium ions were factors in overcoming the toxicity of the aluminum salts. By adjusting the pH of the nutrient solution with citric acid to make it comparable to the pH of the aluminum salt solutions, it was found that the aluminum ion was more of a factor in growth retardation than the hydrogen ion in aluminum salt solutions.

Distribution of Nitrogen in Infusions of Plants. (Walter S. Eisenmenger.) Water infusions of different plants were made in the greenhouse, the plants being kept in the crocks of water for seven weeks. The water or colloidal solution was then filtered off and analyzed for different forms of nitrogen. Except for one corn stover which was simply ground up after it had been kept for one year in a barn, the plants comprised the mature plants including roots and tops, and were timothy, red clover, red top, tobacco, and corn. The latter consisted of the

stalks and roots when the plant was ready to cut. The rate of decomposition was about the same for corn, timothy and red clover. The tobacco decomposed most readily, and the red top least of all.

The nitrogen of tobacco in the filtrate was for the most part protein and ammonia nitrogen, and the red top content resembled the tobacco in this respect to a degree. Corn, timothy, and clover contained, in addition to ammonia and protein, appreciable amino acids, amide, and humus nitrogen.

There was an analogy between those plants causing brown root-rot of tobacco and the N content of the infusions.

Fine Turf Grasses. (L. S. Dickinson.) Further extensive studies are being made concerning the need of pre-seeding fertilization of turf areas. These experiments are being conducted on typical fine turf soil, and turf is growing under natural conditions. The results confirm those obtained in 1931 and 1932 and indicate that on normal soils a single phosphorus carrier is all the pre-seeding fertilizer necessary or desirable for fine turf grasses.

A cooperative experiment has been conducted to compare the value, to turf growers, of American peats and leaf molds with that of foreign peats, when mixed with various types of soil. The results obtained show no evidence in favor of foreign peats.

Through the sponsorship of Merck and Company, chemists, studies have been made of the value of the fungicide, Laboratory Number R. T.–50, for the control of certain fungous diseases of turf grasses. This fungicide was found to compare very favorably in effectiveness with the mercury fungicides commonly used, and the fact that it is neither poisonous, corrosive, nor caustic is a distinct advantage.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in Cooperation with the Massachusetts Agricultural Experiment Station. C. V. Kightlinger, U. S. D. A., in Charge.

Black Root-Rot. (C. V. Kightlinger.) In continued investigation, numerous strains of Havana Seed tobacco were grown in the field during 1932 (the third year of the investigation), in the attempt to find strains of Havana Seed which may be satisfactory under Connecticut Valley conditions, for resistance to black root-rot, type of plant, type and quality of leaf, and producing capacity.

One strain was Havana Seed of the sort that is grown commonly in the Connecticut Valley, which is known to be susceptible to black root-rot, but is acceptable for type of plant and type and quality of leaf produced. This strain was used as a standard of comparison for type. One strain was Havana Seed 142A3, which is known to be satisfactorily resistant to black root-rot. This strain was used as a standard of comparison for such resistance. Of the new black root-rot resistant strains of Havana Seed tested in 1932, six were grown for the first time in 1930, seven for the first time in 1931, and eight for the first time in 1932. In one case these strains were all grown on land which was free or nearly free of *Thielavia basicola*, the fungus which causes black root-rot of tobacco. In another case the strains were all grown on land which was heavily infested with this fungus. Eleven of the new strains were selected for further testing in 1933.

The production of these eleven resistant strains and their checks, in 1932, was as follows:

Strain of Havana Seed Tobacco		Grown on land free or nearly free of *Thielavia basicola*			Grown on land heavily infested with *Thielavia basicola*		
		Yields per Acre Pounds	Grade Index	Crop Index	Yields per Acre Pounds	Grade Index	Crop Index
Common strain		2098	.419	879	1268	.256	325
142A3		2367	.440	1042	1991	.349	695
New strains	No. 10	2612	.442	1153	2083	.373	778
	No. 13	2312	.480	1110	2122	.380	806
	No. 27	2437	.426	1038	1904	.370	704
	No. 22	2400	.432	1036	1940	.434	842
	No. 25	2377	.432	1027	2127	.383	815
	No. 23	2390	.429	1025	2040	.363	741
	No. 18	2338	.423	989	1777	.373	663
	No. 14	2336	.415	969	2171	.393	853
	No. 21	2378	.415	963	1943	.380	738
	No. 15	2342	.406	948	2084	.367	765
	No. 17	2212	.425	939	1821	.395	719

NOTE: Grade Index is a number expressing the grading quality of tobacco produced by a strain in an experiment. It is based upon the percentage yield of grades, and the percentage relationships of these different grades, as given below:

Light wrappers	1.00	Long darks (19″ & longer)	.30
Medium wrappers	.60	Dark stemming (17″ & shorter)	.20
Long seconds (19″ & longer)	.60	Fillers	.10
Short Seconds (17″ & shorter)	.30	Brokes	.10

Grade Index is derived by multiplying the percentage yield of each grade by its respective percentage relationship in the above schedule and adding the products.

Crop Index is a number expressing crop value. It is derived by multiplying the total acre production of tobacco in pounds by the Grade Index value of that particular lot of tobacco.

Grade Index, Crop Index, and the adopted price relationships given above do not necessarily represent commercial values and prices.

Some of these resistant strains deserve testing on a considerably greater scale in numerous places in the Connecticut Valley, to determine their excellence in practical production. One strain was so tested in 1933 and proved to be highly satisfactory that season. Arrangements have been made for such testing of several of these strains in 1934.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Application of the Azotobacter Soil Plaque Test for Determining Mineral Deficiencies in Massachusetts Soils. (J. E. Fuller.) Further studies have been made on plots previously investigated, and several new plots have been added. In all instances the Azotobacter test indicated a deficiency of available phosphorus even though satisfactory crops were grown on all of the plots represented. The results obtained from the tests agreed with those reported by several other investigators, and with those previously reported from this Station (Bulletin 293, p. 14). Tests by Truog's method indicated that the soils studied, with few exceptions, contained sufficient available phosphorus for crop growth. Perhaps some factor in the technique of the Azotobacter test may have been responsible for rendering the phosphorus in the soil unavailable for Azotobacter

growth. In testing acid soils, such as those of this vicinity, it is customary to add an excess of calcium carbonate to the soil to provide a reaction satisfactory for Azotobacter growth. Perhaps the calcium may combine with the phosphorus of the soil to form insoluble tricalcic phosphate which would not support Azotobacter growth. This possibility is being investigated.

Calcium Metabolism of Nitrogen-Fixing Bacteria. (J. E. Fuller.) This is a new project begun in the spring of 1933. The object is to determine whether calcium salts are important in the metabolism of bacteria except as regulators of reaction in the substrata. At present the study is limited to a consideration of the metabolism of Azotobacter. A medium free from calcium has been devised which produces more fixed nitrogen in Azotobacter cultures than is obtained on Ashby's Medium. Suitable reaction in the medium is obtained by the use of di-potassium phosphate. The addition of calcium carbonate in several concentrations has not resulted in greater quantities of nitrogen being fixed by Azotobacter cultures than when the calcium-free medium is employed. Care has been taken, by the use of analyzed chemicals, to obtain a medium which is free from all calcium except that which is purposely added.

Biological Studies of Bacteria of the Coli-Aerogenes Group. (J. E. Fuller.) This is another new project, the purpose of which is to investigate the physiology of, and the influence of environment on, members of the Coli-Aerogenes group of bacteria in the effort to interpret more satisfactorily the results of bacteriological examinations of water and milk. It is proposed to determine, if possible, whether bacteria of this group having different physiological reactions are in reality different species, or merely temporary variants produced by environment. The study has just been started and the time to date has been spent in the collection and purification of cultures.

Laboratory Service. (R. L. France.) Following is a list of the number and types of examinations made in the laboratory during the past year:

Milk (bacteria counts)	1,087
Water	120
Miscellaneous:	
Butterfat	309
Solids	18
Stringiness	1
Total	1,535

The total number of analyses shows a slight increase over the previous year. The milk phase of service is proving of great value to producers, dairymen and local inspectors throughout the Valley.

The number of water analyses compares favorably with the previous year. Through the cooperation of the Engineering Specialist of the Extension Service, it will be possible in the future to make a sanitary survey of polluted private water supplies. By this means constructive suggestions as to the elimination of the pollution will be available, thus giving a most complete service in this field.

The stock of legume cultures has been kept intact and furnished to farmers requesting them for inoculation of leguminous plants.

The Indol Tolerance of the Coli-Aerogenes Group of Bacteria as a Possible Means of Differentiating Fecal and Non-Fecal Strains Occurring in Drinking Water Supplies. (R. L. France.) Results to date indicate a very definite

indol tolerance of certain fecal strains of *Bact. coli.* Information is now being accumulated on the indol tolerance of certain strains of *Bact. aerogenes* and the intermediate group.

A Comparison of Devereux "Yeast Extract" Agar and Standard Agar for Plating Milk Samples. (R. L. France.) A preliminary paper on this subject was read before the Connecticut Valley Section of the American Society of Bacteriologists. The results indicate that the "Yeast Extract" agar has no advantages over the Standard agar when used for determining the bacterial content of raw milk. Further data are being collected to determine the value of the Devereux agar when used for plating pasteurized milk. Studies are being made of several other media which might be used for determining the bacterial content of pasteurized milk. In these studies an incubation temperature of 32° C. is being used in addition to the standard temperature of 37° C.

The Effect of Aging Temperature on the Bacterial Count of Pasteurized Ice Cream Mixes. (W. S. Mueller and R. L. France.) The results of this investigation indicate that ice cream mixes may be held at 68° F. for six hours without any significant increase in bacterial count.

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Black Root-Rot of Tobacco. (W. L. Doran.) In 1932, tobacco was grown for the ninth year in a field last limed in 1923. Its burn this year was unaffected by the earlier liming. It was not of inferior quality, but had shorter leaves than tobacco from unlimed plots.

Tobacco plants in pot experiments were uninjured by ammonium sulfocyanate 800 pounds per acre, applied to soil 11 weeks before planting, but infection by *Thielavia basicola* was not prevented.

Aluminum phosphate 2 tons per acre, applied to soil in pot experiments, did not prevent black root-rot and did not affect growth of tobacco.

Brown Root-Rot of Tobacco. (W. L. Doran.) Growth of tobacco in brown root-rot soil was improved by applications of calcium nitrate and orthophosphoric acid together, but not by either alone. Sucrose 600 pounds per acre, applied to soil free from brown root-rot, did not induce the disease. Copper sulfate 120 pounds per acre had no effect on brown root-rot.

Downy Mildews of Cucumber and Lettuce. (W. L. Doran.) Downy mildew was severe on greenhouse cucumbers in the fall of 1932, but the fungus (*Peronoplasmopara cubensis* (B.&C.) Clint.) did not live on plants in greenhouses after early January. It was next found here in the field on September 2, 1933, the latest recorded date of its first appearance. Many fields escaped it until September 8, when picking was already over.

Soil in which cucumbers were growing (in crocks) was watered only with solutions of copper sulfate (0.29, 0.43, 0.57, 0.86, or 1.0 gram per gallon), applied often enough to keep the soil at or near the optimum moisture content for growth, beginning June 30 (when plants were 10 days old) and ending September 11. Plants were inoculated with *P. cubensis* on September 3. None of these treatments increased resistance to infection by this fungus, and all of them were slightly injurious to the growth of plants.

Soil, 3 inches deep in flats, in which lettuce seedlings were growing, was watered only with solutions of copper sulfate (0.43, 0.57, 0.86, and 1.0 gram per gallon), applied often enough to keep the soil at or near the optimum moisture content for growth. One month after treatment began, tip burn was severe on plants in soil receiving only water, but there was no tip burn on plants watered with any of the solutions of copper sulfate. At this time all plants were inoculated with *Bremia lactucae* E. Regel. Less infection (than the checks) resulted on plants in soil which had received copper sulfate, but plants were injured by the treatment. There was but little infection on plants in soil watered with 1.0 per cent copper sulfate solution, but this treatment was very injurious to plants.

Lettuce plants which had been watered for one month with these solutions of copper sulfate were set in the field, after which they received no more copper. They, too, were inoculated with *B. lactucae*, and the spread of downy mildew on them during the summer showed that no lasting protection had resulted from earlier applications of copper sulfate to the soil.

The following materials (per acre) were applied to soil in pots: potassium carbonate 1000 pounds, hydrated lime 3½ tons, these materials together in these amounts, and copper sulfate 250 and 400 pounds. Lettuce plants were set immediately thereafter. These plants and untreated checks were inoculated with *B. lactucae* 4 weeks later. None of the treatments significantly affected infection. Great injury to the plants was caused by 400 pounds of copper sulfate and by potassium carbonate and hydrated lime applied together.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) The probability of developing varieties of tomatoes sufficiently resistant to tomato leaf mold, caused by the fungus *Cladosporium fulvum* Cke., to prevent crop loss appears promising. Selections have been made of the F_1 and F_2 generations of the hybrids noted in the previous annual report (Bulletin 293, p. 17). The red currant tomato, *Lycopersicum pimpinellifolium* Mill., which is immune to the disease, has been hybridized with Success, Belmont and Break o'Day. Of several tomato hybrids grown in the field, the following showed the highest degree of resistance in the F_2 generation: Bewley II (Stonnor's M. P. X Up-to-Date) with Norduke, Bewley IV (E S 1 X Up-to-Date) with Norduke, Bewley I (Riverside X Up-to-Date) with Norduke, Norduke with Stirling Castle, Up-to-Date with Norduke, and Maincrop with Norduke. The parents of these hybrids possess considerable resistance to the disease, but they are not satisfactory greenhouse tomatoes. Other hybrids with a susceptible and a resistant parent showed no resistance in the F_1 growing.

A spray consisting of 1 ounce of salicylanilide paste (Shirlan H B) and 2½ ounces of sulfonated oil spreader (Agral I), which is reported from England to be very effective in controlling the disease, was used with very good results. Spraying lacks the advantages of sulfur vaporization (see Bulletin 248). A patented sulfur vaporizing apparatus, the "Sulphurator," was investigated and subjected to certain improvements in construction. This ingenious apparatus gives promise of replacing other methods of applying sulfur fungicides under glass.

Eradication of Nematodes in Greenhouse Soils by the Use of Chemicals. (L. H. Jones.) Orthodichlorobenzene has not proved to be a practical substitute for paradichlorobenzene when used with calcium cyanide for the eradication of nematodes in ground beds. The poisonous effect on the plants persists longer and, although more than half the tomato plants were free of nematode galls, there was a greater degree of infection with orthodichlorobenzene than with paradichlorobenzene.

Vegetable Seed Treatments. (E. F. Guba, Waltham.) Organic mercury and red oxide of copper powders consistently gave the best results in controlling damping-off in the greenhouse, and the difference in the merit of the two materials was in general in favor of red copper oxide. Monohydrated copper sulfate in general gave comparatively poor results, but even these were better than with no treatments. In other experiments, dry powdered basic copper sulfates, copper acetates, and copper carbonates gave excellent results. In two extensive field experiments the best stand and growth were obtained from seed treatments with organic mercury and red oxide of copper, while monohydrated copper sulfate proved of little or no value. Further comparative tests of the most promising powders are planned, to determine the best dry seed treatment for each field-sown vegetable crop.

Injury was noted from soaking seeds of tomato, squash, cabbage, and cauliflower in mercuric bichloride solution at recommended intervals and dilutions, while corn and cucumber were not affected. Organic mercury soaks were safe. In view of the excellent stands resulting from seedbed treatments with oxymethylene dusts under glass, and from dry seed treatments in the field, the practice of soaking seeds in liquid mercury disinfectants as an additional means of controlling certain crop diseases in the field is open to question.

Causes and Control of Decay of Winter Squash in Storage. (E. F. Guba, Waltham.) So far, work has been concerned with visitations to squash storages and the culturing of material for study. The following organisms have been isolated from decayed squash: *Rhizopus* sp., *Penicillium* sp., *Acrostalagmus cinnabarinus* Cda., *Hormodendron cladosporioides* E. & H., *Mycosphaerella citrullina* (C. O. Smith) Gross, two undetermined species of Gloeosporium, two undetermined species of bacteria, three undetermined species of Fusarium, and *Bacillus tracheiphilus* E. F. S. The biology of most of these species has been established and the different types of decay resulting from artificial inoculation described.

Complete surface disinfection of Blue Hubbard squash at a temperature range of 60° to 70° F. required 9 liquid ounces of formaldehyde and 6 ounces of potassium permanganate by weight to 1500 cubic feet of space, when the gas was confined 24 hours. Shorter exposures were ineffective, and the merit of weaker doses at longer exposures was not determined.

Strawberry Gold Leaf. (E. F. Guba, Waltham.) The seriousness of this non-infectious chlorotic disease of the strawberry is expressed in inferior plant making and increased susceptibility to winter injury—both of which greatly diminish the yield and quality of berries. Two comparative plots with the same number of mother plants had a difference in yield of 4349 boxes of berries per acre in favor of yellows-free stock. No spread occurred from diseased to healthy rows of plants growing adjacent to each other in the field. Propagation of these plants is being continued for further evidence. Vertical unions of the root crown of diseased and disease-free stock did not result in spread of the disease to the healthy half, or to its daughter plants in the first cropping season.

Diseases of Herbaceous Ornamental Plants Caused by Soil-Infesting Fungi. (W. L. Doran.) This project was begun with work on the effect of certain soil treatments on damping-off and on growth of plants. Except as otherwise indicated, treatments were applied to soil immediately before seeding. The number of grams of material applied per square foot of soil surface and thoroughly mixed with soil is indicated. Soil was 3 inches deep in flats. Most of the damp-

ing-off which occurred was caused by species of Pythium, although Rhizoctonia was also present in some instances.

Results of some of the experiments are tabulated below. The work to date is, of course, only preliminary, and the results should be considered as indicative rather than final.

Material Tested	Grams per Square Foot of Soil Surface	Effect on Damping-off	Effect on Plants
Aluminum sulfate	20	Not controlled	Harmless to all species used.
	25	Not controlled	Some injury to foxglove (*Digitalis purpurea*), aster (*Callistephus chinensis*), and beet.
	30	Not controlled	Injurious to *Primula polyantha* and cucumber; harmless to *Calendula officinalis*, sweet pea, and lupine (*Lupinus polyphyllus*).
	40	Less than check	Somewhat toxic to all species used except Dianthus.
Ammonium hydroxide (1) (sp. gr. 0.9)	1:60*	Not controlled	Harmless to all species used.
	1:50*	Fair control	Harmless to all species used.
	1:40*	Good control	Some injury to *Alyssum saxatile* and sweet alyssum (*Lobularia maritima*).
	1:30*	Good control	Toxic to *Alyssum saxatile*, sweet alyssum, sweet pea, *Scabiosa atropurpurea*, beet and cucumber.
Ammonium sulfocyanate (1)	3	Not controlled	Harmless to all species used.
	5	Not controlled	Harmless to sweet alyssum, Calendula, and beet; slight injury to cucumber.
	6	Not controlled	Harmless to sweet pea and Calendula; injurious to cucumber and sweet alyssum.
Calcium acetate	20	Not controlled	Harmless or somewhat beneficial to Delphinium, hollyhock, mignonette, Salpiglossis, sweet pea, heliotrope, and petunia.
	40	Not controlled	
	50	Less than check	
Calcium cyanamide (1)	10	Good control	Benefited Salpiglossis and *Campanula medium;* harmless to Calendula, sweet pea, and sweet alyssum.
	14	Good control	Harmless to *Alyssum rostratum*, beet, and cucumber; toxic to Scabiosa.
Calcium hypochlorite (1)	4	Not controlled	Toxic to *Centaurea imperialis*, sweet alyssum, and beet.
	8	Not controlled	Harmless to sweet pea.
	12	Less than check	Toxic to sweet pea, *Anchusa azurea*, *Lilium regale*, and nasturtium (*Tropaeolum majus*).
	16	Less than check	Very toxic to foxglove and common heliotrope; slightly toxic to stocks (*Matthiola incana* var. *annua*).
Copper, metallic (a powder, 99.8% metallic copper)	8	Less than check	Toxic to sweet pea, Calendula, beet, and cucumber.
	10	Less than check	Toxic also to mignonette, foxglove, aster, and heliotrope.
	12	Less than check	Somewhat toxic to all species used.
Copper-lime dust (85-15)	15	Not controlled	Injurious in some soils to sweet pea, beet, and cucumber.
	25	Not controlled	Harmless to mignonette.
	30	Less than check	Toxic to Delphinium but not to hollyhock.
Copper sulfate	3	Not controlled	Harmless to sweet pea and garden Verbena; toxic to aster, *Campanula medium*, *Viola cornuta*, and Calendula.
	4	Not controlled	Harmless to beet and cucumber; toxic to mignonette.
	5	Less than check	Toxic to sweet pea, Verbena, beet, and cucumber.
Mercuric chloride	1.5	Not controlled	Toxic to *Campanula medium* and *Arabis albida*.
	2.0	Not controlled	Harmless to sweet pea and Dianthus species; injurious to cucumber.
	2.25	Not controlled	Harmless to sweet pea; toxic to Dianthus and lupine.
Potassium permanganate	10	Not controlled	Harmless to all species used (petunia, Arabis, aster, Aubrieta, beet, and cucumber).
	20	Not controlled	
	30	Not controlled	

Material Tested	Grams per Square Foot of Soil Surface	Effect on Damping-off	Effect on Plants
Sulfuric acid* (sp. gr. 1.84)	9	Not controlled	Harmless to sweet pea; toxic to beet and cucumber.
	12	Not controlled	Harmless to Dianthus and Salpiglossis; some injury to sweet pea and *Campanula medium.*
	15	Not controlled	Some toxicity to *Bellis perennis* and Salpiglossis; no injury to Dianthus species.
Zinc sulfate	10	Not controlled	Toxic to heliotrope, aster, *Physostegia virginiana*, and Bellis.
	12	Not controlled	Not injurious to foxglove.
	15	Not controlled	Toxic to foxglove.

(1) Applied to soil 2 weeks before seeding.
* Applied in water at the rate of 2 quarts of each dilution per square foot.

Carnation Blight. (E. F. Guba, Waltham.) Additional varieties of carnations that were studied and classified for susceptibility to blight caused by the fungus *Alternaria dianthi* S. & H. are the following:

Very Susceptible	Slightly Susceptible	Resistant
Denver	Luminosa	Ocean Spray
Minna Brenner	Mary E. Sim	My Love
Wardelia	Patrician	Satellite
Variegated Ward	Scarlet Monarch	Woburn
Butterfly		Golden Wonder

Infestation of flatted plants with red spider mite contributed to an early epidemic infection of blight in the field as compared with a natural belated infection in the absence of mite. Further tests with potassium permanganate solution as a disinfectant for cuttings before "sanding" substantiated the previous report of the merit of this treatment. No improvement in disinfection was noted by the addition of a spreader to the solution. July benching gave three times as many No. 1 carnations as August benching. Plants made from December, January, February, and March cuttings showed no significant differences in disease control as indicated by yield. Plants housed in August and treated in the field and benches with Bordeaux 4-4-50, containing ½ pint of fish oil, gave twice as many No. 1 carnations as similar plants not treated.

Monograph of the Genus Pestalotia. (E. F. Guba, Waltham.) The interest manifest in this study has stimulated efforts to carry it further. During the past year exsiccati collections from the Berlin Botanical Museum and from Dr. Charles Fairman were examined, making possible much progress in the work.

Forcing Gladiolus with the Aid of Artificial Light. (L. H. Jones.) Supplementing daylight with artificial light from 500-watt bulbs is a practical method for securing blossoms of gladiolus, variety Crimson Glow. At least three weeks of this light are necessary for the formation of flower spikes, and the greatest number of spikes was obtained from plots that received ten or more weeks of light at night. It was quite noticeable that the earliest blooms were obtained from the plots that received light less than ten weeks. This bears out the results of previous experiments which show that a little light shortened the period required for blossoming, while prolonged exposure to light lengthened the period.

Plant Containers. (L. H. Jones.) Plant containers of copper and brass, with and without drainage holes, have been tested. A variety of house plants, both

flowering and foliage, did better in these metal containers than in clay pots on a dry surface. There was no sign of copper injury and a chemical analysis showed no indication that copper had been absorbed by the plant from the copper in the container.

In other tests of the effect of copper on plants, copper containers did not prove harmful to plants grown in them for a period of 200 days. Neither did solid pieces of metallic copper, buried in the soil in glass tumblers in which three crops of tomato plants were grown over a period of 225 days, have any effect on the plants. Metallic copper in powder form, however, proved injurious to plants, the effect varying with the type of plant. In some cases the plants produced yellowish or pale yellow leaves; in others, the plants were stunted and produced few if any new roots.

Jardinieres are practical coverings for clay pots if they are close-fitting. However, if there is a large air space between the pot and the jardiniere, better results will be secured if this space is filled with moist sphagnum moss.

An enamel paint is a satisfactory means of making clay pots nonporous. To prevent chipping, the pot should be clean and dry before the paint is applied and the pot should be painted inside as well as outside.

The ordinary clay pot is not satisfactory unless it is used on a moist surface. For use in offices and living rooms, moist sphagnum moss under the pot has proved more satisfactory than either moist sand or sponge rubber. The moist sand apparently withdraws nutrients from the pot, and the sponge rubber allows too much free water to come in contact with the pot, thereby keeping the soil too moist.

Nutrients, particularly soluble nitrogen, may find ingress or egress through the moist wall of a clay pot. The direction of the flow is determined by the concentration of the nutrients in the moist medium on which the pot rests. If the medium is sand, the nutrients are absorbed by the sand; if soil, the nutrients may pass from the soil beneath the pot through the pot wall and benefit the plant. Plants that were yellow because of nitrogen deficiency recovered in 10 days to a normal green color after the drainage holes were plugged and the pots were moved from a cinder bench to a bench of soil. Plunging pots in soil undoubtedly increases the feeding range of the potted plant in addition to cutting down water loss by evaporation from the wall of the pot.

THE CRANBERRY STATION

(East Wareham, Massachusetts)

H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Control of the Cranberry Root Grub (*Amphicoma vulpina*). Flooding to control this insect, described in the last annual report (Bulletin 293), was tried on another bog this season, the winter flood being let off early in April and the bog being reflooded from May 17 to July 5. The treatment was again highly successful and probably may now be safely regarded as very reliable.

Pyrethrum Dust. (Dr. E. A. Richmond, employed locally by the Crop Protection Institute, cooperating.) Research work with pyrethrum dust mixtures was continued extensively during the past season. Satisfactory power machines for applying the dust on a large scale were developed by local manufacturers, and

hundreds of acres were dusted commercially. In both the research and commercial dusting, all the dusts used were mixtures of fine ground pyrethrum flowers and 300-mesh gypsum. Following is a summary of the results of the season's experience with these dusts (the pyrethrum dust used in the mixtures having a 1 per cent pyrethrin content in all cases).

Insect	Stage of Growth	Pounds of Mixture per Acre	Per Cent Pyrethrum Dust	Control
Gypsy Moth (*Porthetria dispar* L.)	Caterpillars (well-grown)	100	40	50 per cent
		200	50	Complete
Cranberry Spittle Insect (*Clastoptera vittata Ball*)		150	50	Satisfactory
Cranberry Black Bug (*Plagiognathus repetitus Knight*)		150	33 1/3	90 per cent
False Army Worm (*Xylena nupera* Lint.)	Worms	100	33 1/3	Good
Brown Cranberry Spanworm (*Ematurgia amitaria* Gn.)	Worms	100	33 1/3	Good
Blackheaded Fireworm (*Rhopobota vacciniana* Pack.)	Worms	100	25	Very good
	Worms	100	20	Often effective
	Moths	100	20	Very Effective
Cranberry Girdler (*Crambus hortuellus* Hubner)	Moths	100	20	Very Effective
Green Cranberry Spanworm (*Itame sulphurea* Pack.)	Worms (all stages)	100	30	Good
Blunt-nosed Leafhopper (*Ophiola striatula* Fall.)	Young stages	100	15	Satisfactory
	Young stages	100	10	Often effective
	Later stages	100	30*	Satisfactory
Cranberry Weevil (*Anthonomus musculus* Say)		100	50	Not appreciable

*Since this mixture is strong enough to materially reduce infestations of several other important bog pests, its use is perhaps advisable in spite of the cost. The last week in June is probably the best time to treat this leafhopper, all things considered.

Work with Chemical Weed Killers. (W. H. Sawyer.) In preliminary tests from July 28 to August 29, 1932, to find out the effects of weed killers on cranberry weeds and cranberry vines, the following chemicals were tried in different strengths of solution and sometimes in combination with one another: Sodium chlorate, iron sulfate, copper sulfate, sodium arsenite, sodium arsenate, sodium chloride, calcium chloride, ammonium chloride, sodium hydroxide, sodium bisulfate, calcium hypochlorite, zinc chloride. Of these twelve chemicals, sodium arsenate seemed to promise best results. Sodium arsenite and sodium chlorate proved to be excellent killers for cranberry weeds, but in concentrations effective on weeds also killed cranberry vines equally well. The highest differential between injury to weeds and injury to cranberry plants was secured with weak solutions of sodium arsenate. As low a concentration as 10 pounds per acre in 550 gallons of water, applied as a spray, was found to effect a complete kill of the aerial portion of wild bean (*Apios tuberosa*) with no noticeable injury to cranberry vines. Brambles and some of the lesser weeds were also killed, but on poison ivy the sodium arsenate was ineffective in concentrations low enough not to injure cranberry vines.

Weather Observations. (H. J. Franklin.) Further records bearing on frost forecasting were made for the Station by observers at East Wareham, North Harwich, East Gloucester, Carlisle, Fitchburg, Worcester, and Holliston. These records and those of previous years were studied intensively, and the formulae for predicting minimum bog temperatures were carefully revised to accord with them.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station. H. F. Bergman, Senior Pathologist, U. S. D. A., in Charge.

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman, W. E. Truran, and Jos. L. Kelley.) Selected wild vines collected in Maine in 1932 were set out on the State Bog. Most of the vines made good growth and will be ready for propagation in 1934. Seedlings have been grown from seeds of fruit from naturally pollinated flowers of the Early Black, Howes, and McFarlin varieties to determine whether or not variations in the resistance to false blossom will be found in seedlings segregating out in the progeny. Seeds from reciprocal crosses of Early Black and McFarlin made in 1932 were planted, but none of the seeds germinated.

Oxygen Content of Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman and W. E. Truran.) Further experiments were made to determine the effect of the absence of oxygen in winter-flooding water on the development of terminal and fruiting buds during the following season. They indicate that low oxygen content in the winter-flooding water causes a retardation of development of terminal buds and, when oxygen content approaches complete absence, many of the terminal buds are killed. Flower buds of Early Blacks and Howes on the State Bog and some other nearby bogs were tagged and their development was followed throughout the growing season. Counts of fruit set from these buds indicate, as in last year's counts, that on the basis of the total number of fruits set from the total number of uprights examined, with one exception, more fruits were set from large or medium sized terminal buds than from small ones. The exception was found in one section of Howes on the State Bog where the winter flood was shallow. Here 48.3 per cent of the flower buds from small terminal buds set fruit as against 42.9 per cent for the medium and 41 per cent for flowers from large terminal buds. In deeper water on the same section the fruit set from flowers from large terminal buds was 41.2 per cent; from medium, 35.8 per cent; and from small ones, 31.8 per cent. These variations have not been correlated with oxygen content of the winter-flooding water.

Regeneration of False Blossom Bogs. (H. F. Bergman and Jos. L. Kelley.) Commercial weed killer (sodium arsenite) was applied to only one bog during the past season. The weed killer was applied on two plots: on one at the rate of 800 gallons per acre; and on the other, 1000 gallons per acre. The higher rates of application appeared to be more satisfactory than lower ones.

Experiments were started on another bog to determine the effect of heavy sanding, and of heavy sanding plus use of fertilizer, on the reduction of the amount of false blossom.

Vines of the Howes variety on these experimental plots showed a marked improvement both with sanding alone and with sanding and subsequent fertilization, as compared with untreated areas.

Spraying Experiments with Bordeaux Mixtures. (H. F. Bergman, W. E. Truran, and Jos. L. Kelley.) Spraying experiments similar to those of the preceding year were carried out during the past season. Spraying experiments on one of the bogs previously used were discontinued and experiments were begun on two other bogs. In nearly all instances this season two applications of spray proved to be as effective in controlling fungous rots as three. All sprayed plots, however, showed improvement over unsprayed plots, although in a few instances as much as 15 to 20 per cent of rot was found on plots which had been sprayed two or three times.

In order to test the effect of Bordeaux spray when applied to open flowers, about 100 uprights on each of 12 to 14 plots were tagged. Each upright had some open flowers and some unopened buds. These uprights were examined again late in the summer to determine the number of fruit set. The average set for all blossoms, including both sprayed and unsprayed, was 33.8 per cent; for those sprayed when open 34.3 per cent; for those sprayed in unopened bud stage 28.1 per cent. There is no indication that applying Bordeaux to fully open flowers causes any reduction in the number of fruit set.

Storage Test of Cranberries. (H. F. Bergman and W. E. Truran.) Berries from experimental spray plots stored in the basement of the State Bog building at air temperature showed less loss from fungous rots than those from unsprayed plots. Most of the loss occurred early in the storage season. With berries of early varieties, nearly all of the fruit from unsprayed plots was rotten by November 15, while those from plots receiving two or three applications of spray have shown a loss of only about 30 to 40 per cent up to December 15. Berries of late varieties have shown a similar behavior, but the rot has not developed as early as in the early varieties. Berries from plots which were sprayed twice have kept as well as those from plots sprayed three times.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

The Effect of High Initial Aging Temperatures on Certain Physico-Chemical Properties of Gelatin Dispersions. (W. S. Mueller.) The results of this investigation have been published in *Industrial and Engineering Chemistry* 25:707, June 1933.

Studies on Melting Ice Cream. (W. S. Mueller.) Investigational work on the use of higher aging temperatures in the manufacture of ice cream has revealed a new cause for excessive retardation and curdled appearance of melting ice cream. The results of the experiments have been published in the *Ice Cream Trade Journal*, October 1933.

A Study of the Use of Higher Aging Temperatures in the Manufacture of Ice Cream. (W. S. Mueller and J. H. Frandsen.) A full report of this investigation has been published in Bulletin 302.

The Theoretical Causes of the Factors Involved in the High Initial Aging Temperature Phenomena. (W. S. Mueller.) The effect of high aging temperatures on the Tyndall phenomenon of gelatin-water solutions is being studied. The accuracy of the instrument used in making these Tyndall observations

depended largely on the human eye, which at best is never exact. A new Tyndallmeter, using photo-electric cells, is being developed in order to attain greater accuracy.

Stabilizers for High Fat Ice Cream. (W. S. Mueller.) During the past few years a number of ice cream manufacturers have been selling an ice cream high in fat (16-24 per cent). This brings up a new problem; namely, what is the best stabilizer for this new product? Very little experimental work has been reported on the stabilization of high fat ice cream. The purpose of this study is to determine the amount of gelatin needed for high fat ice cream, and also to determine the advantages and limitations of the following proposed gelatin substitutes as a high fat ice cream stabilizer: Krabyn, Hygell, Yelkin, Kelco-gel, Lakoe, Galagum, and Pectin. Some of these proposed stabilizers will also be used in conjunction with gelatin.

A chemical analysis of the stabilizers to be used in this study has been made by E. B. Holland, Department of Plant and Animal Chemistry. Studies on the effect of these various stabilizers on the quality of the ice cream have not progressed sufficiently to make possible definite conclusions.

The Effect of Aging temperature on the Bacterial Count of the Ice Cream Mix. (W. S. Mueller and R. L. France.) This research has shown definitely that a pasteurized ice cream mix may be aged for six hours at 68° F. with no significant increase in bacterial count. Indications are that a mix may even be held 10 hours at 68° F. with no significant increase in bacterial count. These results are contradictory to a general belief in the ice cream industry that a pasteurized ice cream mix must be cooled to approximately 40° F. immediately after homogenization in order to avoid marked increases in bacterial growth. Probable reasons for this lag in bacterial growth are being studied.

Some Factors Affecting the Properties of Whipped Cream. (W. S. Mueller, M. J. Mack, and H. G. Lindquist.) The purpose of this project is to study factors, either neglected or inadequately studied in previous research, which affect the whipping of cream and the stability of the finished product.

Some previous studies on whipping cream are open to criticism because manually operated whippers were used which prevented whipping under standard conditions to a given degree of stiffness. In this investigation a mechanical whipper has been connected with a sensitive wattmeter so that the whipping process can be carefully studied and controlled. Preliminary trials with this method have shown that both the rate of whipping and the stiffness of the whipped cream can be measured at any time in the process with considerable exactness. A method of this type should be used in the control laboratory as well as for research since minor differences, often overlooked in hand whipping, are easily detected with a mechanical whipper which has a constant speed.

Preliminary studies have been made on the following factors:

1. Effect of percentage of fat.
2. Effect of temperature.
3. Effect of aging.
4. Effect of delayed cooling.

A Study of Ice Creams High in Fat Content. (M. J. Mack.) A tendency towards the manufacture of richer ice cream has been evident in New England for several years. Keen competition within the industry, coupled with lower ingredient costs, undoubtedly are factors which have an important bearing on the increased use of richer ice creams.

Ice creams which are considered high in fat have a butterfat content of 18 per cent or more. In the manufacture of these rich ice creams two serious difficulties have been encountered. One is an excessive viscosity which interferes with efficient homogenization, cooling, freezing, and packaging. The other is a very undesirable melting appearance. When served, the ice cream does not melt into a creamy liquid but remains rigid as a whipped cream would. Often a clear liquid oozes from the mass. This condition is undesirable because the consumer often assumes that inferior ingredients have been used or an excessive amount of stabilizer has been added.

Results indicate that excessive viscosity can be largely prevented by using higher pasteurization and homogenization temperatures (155 to 160° F.) and homogenizing with a duo-valve machine. However, passing the ice cream mix through both valves of a two-stage machine still permits considerable clustering of the fat globules. These clusters of fat globules materially increase viscosity. Trials have been conducted with a reducing valve on the discharge line of the homogenizer, carrying from 100 to 150 pounds of pressure as far as the reducing valve. The ice cream mixture is released from further pressure as it passes through the reducing valve. This additional treatment almost entirely eliminates clustering of fat globules, and as a result the homogenized product is sufficiently low in viscosity.

Improvement in the melting appearance of ice cream high in fat content is another benefit of the procedure just discussed, for the prevention of fat globule clustering also improves melting appearance. At present a study is being made with different sugars in the hope of decreasing the resistance to melting. It is hoped that the use of glucose or some other simple sugar in combination with sucrose will prove beneficial in securing a desirable melting appearance of ice creams high in fat content.

The Vitamin C Content of Strawberries and Strawberry Ice Cream. (C. R. Fellers, Horticultural Manufactures, and M. J. Mack.) This study was planned to determine whether or not preservation of strawberries by freezing or their subsequent use in strawberry ice cream decreased the vitamin C content of the fruit. Bio-assays were conducted with guinea pigs on fresh and frozen strawberries and strawberry ice cream. The study, which was completed during the past year, showed that preservation of strawberries by freezing, with or without sugar, has no harmful effect on the vitamin C content of the fruit. The incorporation of strawberries into ice cream and the rigorous beating during the freezing of the ice cream caused no measurable loss of vitamin C. This is attributed to the low temperatures at which agitation, air incorporation, and storage of the ice cream takes place.

A Study of the Changes That Occur in the Storage of Frozen Sweet Cream. (H. G. Lindquist.) Some progress has been made, but thus far no methods have proved satisfactory in measuring the changes that occur in frozen cream.

The Comparative Efficiency of Electrically Operated Tanks versus Ice in the Cooling of Milk. (J. H. Frandsen.) Where electricity was used in cooling four cans of milk from 90° to 45° F., it was found that 1.2 KWH were required for each 100 pounds of milk; and when ice was used, 40 pounds of ice were required to accomplish the same results. Comparison in dollars and cents can best be made in each locality by using the prices for electricity and ice that prevail in the local community.

A Study of the Possibilities of Milk, Cream, and Plastic Cream in the Development of New Products such as Combinations with Honey, Fruits, and Flavors of Various Kinds. (J. H. Frandsen and C. R. Foskett.) This project is well under way. Several batches with varying percentages of honey, cream, fruits, and nuts of various kinds have already been made and partially studied.

DEPARTMENT OF ENTOMOLOGY

A. I. Bourne in Charge

Investigation of Materials Which Promise Value in Insect Control. (A. I. Bourne.) The early spring of 1933, like that of 1932, was characterized by favorable weather conditions for dormant and delayed dormant spraying and very little interruption of spraying operations resulted. The delayed dormant application of oils was made on April 20 and 21. Strong winds, which promoted rapid drying, prevailed during both days. Due to the protected position of the experimental blocks, there was no interference with the application. Following the application was a week of uniformly cold weather, with temperatures not low enough to cause any breakdown of the oil sprays but sufficient to retard the rate of bud development so that ample time was allowed for the application of oils.

The investigation narrowed down to a study of comparatively few samples which appear to be outstanding in their class and show promise of effectiveness worthy of recommendation. Oil emulsions of the General Chemical Company, of the Niagara Sprayer and Chemical Company (Peninsula Oil Emulsion), and of the California Spray Chemical Company were included in the tests. The new type of "pourable" Kleenup proved to be fully as effective as the older type and much more convenient to handle.

In the face of a comparatively light infestation, all of the oils tested showed excellent control, even at moderate dilutions. This emphasizes the fact that against a moderate infestation of red mite thoroughness of application is of even greater importance than the particular brand of oil used, and that moderate dosage is sufficient under these circumstances for satisfactory control.

Preliminary tests were made with the Vapo-Duster, a new development in the use of oil sprays. By this process refined oils, either alone or combined with highly concentrated insecticide or fungicide materials, are diluted with air to form a fog which rapidly envelops plants or trees and covers any pests present with a uniform film of the active material. In such an application oils are used undiluted with water, and the spray material is atomized and driven upon the plants and pests at considerable pressure. This method eliminates the necessity of hauling large quantities of water and the loss of time for frequent refilling. The fixed type of discharge on the present machine will require modification for adaptation to average orchard conditions. The new method, however, reduces the time of application very materially, and on those trees where thorough coverage was secured, a very high percentage of overwintering eggs of red mite was killed. The effectiveness was equivalent to that of the conventional oil sprays.

In tests against the Mexican bean beetle, Dutox, a commercial fluosilicate compound, was applied as a dust and used at dilutions of 1 part to 2 and 1 to 3 of hydrated lime. No injury to bean foliage resulted from either application. From the results of previous tests no injury would be expected from this material at these dilutions except under conditions of very high temperature and humidity.

The effectiveness of this material compared very favorably with that of magnesium arsenate, the standard treatment; furthermore, reinfestation was very slow following the application of Dutox. Manganar, a manganese arsenate, diluted with hydrated lime at the rate of 1 part to 4 and applied as a dust, caused very severe burn. Nicotine sulfate (1-800) and Red Arrow, a pyrethrum compound, (1-400) proved effective as contact sprays. They reduced the numbers of bean beetle larvae but reinfestation was rapid, and consequently with such sprays frequent applications are necessary. Tests with pyrethrum dust and a rotenone dust showed these materials to have an excellent initial effect upon bean beetle larvae but neither of them appeared to have the residual effect of the fluosilicate compound mentioned above nor did they furnish protection over as long a period as the standard treatment with magnesium arsenate.

In most of the plantings of gladiolus, where the corms had been given the dormant treatment with either hydrocyanic acid gas or naphthalene, the gladiolus thrips did not develop to serious numbers until comparatively late in the season; and in many fields well isolated from other plantings, thrips were relatively scarce throughout the season and caused practically no damage—another demonstration of the effectiveness of these dormant treatments. Collections during this season showed that undoubtedly more than one species of thrips attack gladiolus. This explains why, in some fields where the corms were treated during the dormant period and consequently were free from thrips when planted, a serious infestation developed during the early season. This strengthens the recommendation that all crop remnants, chaff, etc., be destroyed after the bulbs are pulled in the fall and that, so far as possible, weeds and grass on the margin of plantings be burned over to kill thrips hibernating there. Of the spray materials and combinations tested, the Paris green–molasses spray showed to best advantage based on the appearance of the florets as well as on the effect upon thrips. A pyrethrum dust also gave good results. Derrisol (1-600), pyrethrum spray (1-600), and a combination of nicotine sulfate (1-800) and Penetrol (½ of 1 per cent) proved to be about equal in value but were slightly less effective than the Paris green–molasses spray. Dusting sulfur proved to be unsatisfactory.

The studies of various substitutes for lime-sulfur, carried on in cooperation with the Pomology Department, were confined chiefly to those materials which had proved outstanding in previous tests, with the addition of two new materials recently developed which appeared to be especially promising. All of these were used in combination with lead arsenate, and the complete schedule of seven sprays was followed. The efficiency of each material was measured in comparison with the standard lead arsenate and lime-sulfur combination.

The wettable sulfurs were applied in the sprays after the special curculio following the use of lime-sulfur as a fungicide up to and including the calyx. In all cases the special curculio application comprised lead arsenate and fish oil without any fungicide.

Further studies were made on the effectiveness of Kolofog and of flotation sulfur when used throughout the season as compared with the results secured when these materials were used following lime-sulfur in the pre-blossom sprays.

A combination of magnetic sulfur and lime-sulfur with lead arsenate was also applied in a complete schedule. It was hoped such a combination would give effective control against scab, avoid the burning that usually follows lime-sulfur in summer applications, and at the same time provide a spray more economical than the commercial brands of wettable sulfurs.

The lime-sulfur–lead arsenate combination again caused more or less burn

to foliage. Little russeting of fruit was noted, however. None of the other combinations caused foliage injury.

The value of these materials in controlling disease and insect pests is shown in the following table, based on examination of the McIntosh crop at harvest.

Treatment	Percentage of Clean Fruit	Percentage of Fruit Showing Injury From:		
		Curculio	Codling Moth	Scab
Lime-sulfur	82.7	9.0	4.5	.4
Lime-sulfur Lime	90.6	.5	1.6	6.7
Sulcoloid (entire season)	50.2	.9	2.0	47.0
Sulcoloid (after lime-sulfur)	55.9	.6	.6	41.3
Apple Dritomic (entire season)	49.2	.6	T	47.4
Apple Dritomic (after lime-sulfur)	87.7	1.1	.6	8.5
Magnetic Spray Lime-sulfur	94.1	T	1.9	1.5
Kolofog (entire season)	84.1	—	T	14.8
Kolofog (after lime-sulfur)	89.1	.4	1.0	8.0
Flotation sulfur (entire season)	98.1	.3	.3	.9
Flotation sulfur (after lime-sulfur)	96.3	.4	1.4	.8
Check	1.1	49.6	13.9	92.4

The addition of hydrated lime to the standard lead arsenate–lime-sulfur combination gave a greater percentage of clean fruit and less insect damage than when this material was omitted. It did not hold scab as well as did the combination without lime.

Sulcoloid and Apple Dritomic combined with lead arsenate proved rather disappointing in control of scab. The control of insects by these combinations was excellent and but for the large amount of scab present both of these materials would have allowed over 90 per cent of clean fruit. In fairness to these materials and their manufacturers, it should be stated that during the application of the pink spray a heavy rain interrupted the spraying, and these two materials had to be applied the day following the rain. This rain marked one of the first periods of scab infection and the delay of one day in applying these sprays allowed infection to take place. The materials merit further tests.

The combination of magnetic sulfur—lime-sulfur—lead arsenate gave excellent control of both insects and scab and allowed 94 per cent of clean fruit. Kolofog again showed to better advantage when it followed lime-sulfur in preblossom sprays. Flotation sulfur gave excellent results, with a slight advantage in favor of the use of lime-sulfur in the sprays before the calyx.

Even a casual glance at the record of the fruit from the unsprayed checks should answer the question, "Does spraying pay?"

Control of Onion Thrips. (A. I. Bourne.) Onion thrips were more abundant in 1933 and the infestation more uniform than for several years. Observations throughout the Connecticut Valley during the growing season revealed heavy infestations of fields of seed onions well isolated from sets, a condition that differed greatly from experience in previous seasons.

Weather conditions during June and July proved to be unusually favorable for the rapid multiplication of thrips. Weather during June was considerably warmer than normal, with very high temperatures on several days. With the exception of two heavy storms, the precipitation of the month was comparatively insignificant. July with its hot weather and accompanying drought was even more favorable for the development of thrips. This and the early maturing and harvesting of sets resulted in an unusually heavy infestation on seed onions. Although the peak of abundance occurred at the usual time (the last week of July and first of August), the rise to this point was more gradual and began much earlier than normal. Consequently seed onions particularly were subject to an unusually heavy infestation over a long period and the damage was correspondingly heavy.

While the sprays applied for thrips control gave as high a percentage of kill as formerly, migration from surrounding fields was so constant that heavy reinfestation took place very rapidly, demonstrating that in any similar season at least one and probably two extra applications would be necessary to give protection over the unusually long period of danger.

Several insecticides and combinations were tested and their effectiveness compared with the standard nicotine sulfate–soap combination. The best control was obtained from the nicotine sulfate–fish-oil soap spray. Lethane and Penetrol proved to be a close second in effectiveness. Its cost is, however, somewhat prohibitive.

The plots treated with naphthalene flakes showed comparatively slight damage from thrips, and this treatment appears to be very promising. The combined spray of Paris green and molasses, so successful in the control of gladiolus thrips, caused considerable injury to onion foliage after each application. The material DAO, a dry powder, broadcasted along the rows checked the thrips but its cost is prohibitive for use in large acreages. The pyrethrum dust was shipped so late that only one application could be made. The results were so promising it is worthy of further study.

The fungous disease of thrips which was so generally distributed throughout the Valley during 1932 and caused a rapid decrease in the numbers of thrips was present this season, but was much less abundant and was later in appearing. Its appearance coincided with the normal drop in thrips abundance which occurs early in August, so that it was of much less benefit than in 1932. It was, however, present over practically the same area as in the preceding year, and leads to the hope that it might survive an unfavorable season and build up a heavy infection in a year when conditions were more favorable.

The Spray Residue Problem. (A. I. Bourne.) The recent activity of governmental agencies and the establishment of limits of tolerance for lead and for fluorine compounds upon harvested fruit and vegetables, in addition to those already fixed for arsenic, have combined to reemphasize this problem and necessitate additional investigation.

The limit of tolerance first proposed for lead was so low that further study of arsenical residue became necessary, and no tolerance on fluorine residue was recognized. These regulations were subsequently so modified for the 1933 season that drastic changes in the spray schedule were not necessary, and a limit of tolerance for fluorine residue, equal to that for arsenic, was established.

The strict limits first proposed for lead residue necessitated a study of possible substitutes for lead arsenate. Tests were made of seven different brands of calcium arsenate, a manganese arsenate, and a zinc arsenate. All of these caused

serious burning of foliage. Similar tests in commercial orchards in many cases resulted in even more serious damage than that in the college orchards. Burn was first noted following the extremely hot weather in late June, and in many subsequent instances was associated with similar periods of high temperature, particularly when accompanied with a high relative humidity. Lead arsenate in parallel tests and under the same conditions caused slight foliage burn but in no case was the injury comparable to that following calcium, manganese, or zinc arsenate.

Weather conditions during late summer and early fall, particularly during the period from the last spray or dust application until the harvesting of the fruit, were favorable from the standpoint of the residue problem. The total rainfall during August was nearly two inches over the normal and the outstanding feature of the weather during September was the unusually large rainfall of over twelve inches, a great part of which occurred just before the harvesting of McIntosh. From the residue standpoint the danger to the main varieties, McIntosh and Baldwin, was practically eliminated, and growers who dusted in the late season applications experienced no difficulty.

In cooperation with the State office of the Food and Drug Administration, samples of McIntosh and Baldwin were collected and forwarded for analyses for both lead and arsenic to determine how far the present spray schedule could be safely followed and what changes would be necessary. The results of these analyses have not been received. The excessive rainfall during August and September would so reduce the amount of residue at harvest that it is doubtful whether these figures would be applicable to a season of more normal precipitation.

Under present conditions, if a grower hopes to avoid the danger of lead or arsenical residue without the necessity of washing his fruit, it is recommended that lead arsenate in an amount exceeding 3 pounds to 100 gallons should not be applied within 8 weeks of harvest and that no arsenical spray be applied within 6 weeks of harvest. Growers who depend upon dusting, however, may safely employ at least a 90-10 sulfur–lead arsenate dust as late as 4 weeks before harvest.

Systematic Study of Oil Sprays. (A. I. Bourne in cooperation with the Department of Chemistry.) Three samples of miscible oil, prepared under identical conditions and with the same emulsifying agents, were used in the tests this season. The basic oils were paraffin base lubricating oils of approximately the same viscosity. The specific gravity of the samples was respectively 0.86, 0.89 and 0.91, and the samples varied from 75 to 86 per cent in their degree of unsulphonated residue. These were applied in a block of plums while the trees were in delayed dormant stage of bud development, to test their effectiveness against overwintering eggs of European red mite. They were used at 2 and 3 per cent strengths of the basic oils.

When mixed with water in preparation for the spray, the samples of higher specific gravity went into solution very readily. The sample of 0.86 specific gravity was emulsified with considerable difficulty and required constant and vigorous agitation. None of the samples when once in solution showed any evidence of breakdown or separation of free oil. There was no indication of burn or retarding of bud development following the application of any of these oils, at either dilution.

All of the samples gave 98 to 99 per cent control of European red mite. There was no significant difference in effectiveness in any case; but the light infestation of red mite in the college orchards made any fine distinctions in effectiveness impossible.

Apple Maggot Control. (A. I. Bourne.) A combination of favorable weather conditions, especially during the period of emergence of the flies, which allowed the insect to follow closely its normal course of seasonal development and more accurate timing of the sprays for its control, enabled growers to hold the pest in check very satisfactorily. At the same time there was sufficient evidence from unsprayed blocks to show that this control was not due to any scarcity of the insect over the State as a whole.

In the 9 orchards where control demonstrations have been conducted and in which the complete control program was continued, only 9 apples out of a total of 7,688 examined were found to be infested, an average of 0.12 per cent infestation; in 5 of the orchards no evidence of maggot injury was discovered; and in only one block did the fruit score less than 90 per cent clean. One grower, whose fruit scored less than 3 per cent clean in 1929, the year preceding the demonstration, largely because of failure to control apple maggot, secured in 1933 a crop scoring 93 per cent clean fruit with no evidence of maggot injury.

The work was extended from a demonstration in individual orchards to an attempt at a community program in so-called maggot control areas where several growers, whose blocks were located in a well-defined area more or less isolated from outside orchards, were united in a campaign to control maggot in that area. The success of such a plan depends upon the thorough cooperation of all the growers. Results showed that successful maggot control was in direct proportion to the extent to which each grower carried out his assignment.

In one area comprising approximately 15,000 trees in commercial blocks, apple maggot damage of from 5 to 10 per cent on Baldwins was recorded when a complete spray program was supplemented by the removal of wild, pasture, or roadside trees in the vicinity of the commercial orchards. Where the environmental factors were ignored, and neglected trees were allowed to remain standing, from 60 to 100 per cent of the fruit was found to be infested by maggot, and in nearby commercial blocks the fruit showed from 20 to 50 per cent infestation. Many hawthorn trees were found in this area and much of the fruit was found to contain maggots.

In a somewhat smaller area where, by the united efforts of the group of growers, all neglected trees were removed and an adequate spray program was carried out in all the commercial blocks, the infestation on Baldwins ranged from 0 to 7 per cent, with an average infestation of 1.8 per cent. In all but one case maggot damage was less than 2 per cent and in every case maggot injury was much less than that of the previous year.

Studies on the dispersal of apple maggot flies, supplementing those of Phipps and Dirks in Maine, led to recovery of flies at a distance of from 600 to 700 yards from the point of liberation. The maximum range in previous records of recovery was approximately 300 yards. This indicates that under favorable conditions these insects may fly for longer distances than previously supposed, which may account for severe outbreaks which have hitherto been baffling to explain.

Introduction of Parasites of Oriental Fruit Moth. (A. I. Bourne.) The introduction of parasites of the Oriental fruit moth was extended to practically every section of the State where peaches are grown on a commercial scale and where the infestation of Oriental fruit moth was severe enough to promise successful establishment of the parasites.

Approximately 60 colonies comprising 15,000 specimens of *Macrocentrus ancylivorus* were liberated in 8 counties of the State. In addition, liberations were made of several colonies of newly introduced parasites, some of which

appear more promising than any of the native species. The work was carried on in cooperation with the U. S. Bureau of Entomology and the liberations were made under the direction of the various county agents.

Twig collections previous to liberation indicated that the parasites were not present naturally in these counties. Similar collections made in late summer from the orchards where colonies of *Macrocentrus* were liberated showed that in every case the parasites had become well established. Further studies will be necessary to determine whether the insect can successfully winter over in all sections of the State. Recovery records from orchards in Hampden County, where liberations had been made in previous years, showed from 43 to 88 per cent of parasitism.

Plum Curculio. (W. D. Whitcomb, Waltham.) Continuing previous experiments to determine the effect of temperature on the activity of the plum curculio, 140 pairs of adult curculios were divided into 4 groups of 35 each. The groups were confined for periods of 10 and 20 days at 55°, 65°, 75°, and 85° F., after which they were transferred to the other temperatures in the series for a similar length of time. Daily records were kept of the activity of the beetles, as indicated by the number of feeding punctures per beetle and the number of eggs laid by each female. These experiments clearly verified the results of previous work which had shown a consistent increase in both feeding and oviposition with each increase in temperature.

In general the average activity of the beetles when placed in a certain temperature at any time regardless of the previous environment was consistent with the average activity during a continued exposure to that temperature. An exposure to a higher temperature increased activity, and to a lower temperature decreased activity with one exception. This exception was recorded when a 20-day exposure at 85° F. showed slightly less activity than a previous 10-day exposure at 75°. Other observations as well as this exception indicated that there is a tendency toward decreased activity at temperatures above 75°.

The average number of feeding punctures per beetle per day during 10 days at 65° F. was 3.02, while this activity during a similar exposure after a 20-day confinement at 55° was 3.54, indicating that a low temperature not only retards activity but also produces a supply of stored energy which results in a slight supernormal activity when the temperature is increased. It also appeared that a similar reaction in the opposite direction took place, when it was observed that the average number of punctures at 55°, 65°, or 75° was less after a previous exposure of 10 or 20 days at 85° than at a constant exposure to those temperatures. Oviposition records were similar but showed more variation.

Laboratory tests of several stomach poisons which might be more desirable to use than lead arsenate for combating the adult plum curculio indicated that both calcium arsenate and manganese arsenate were slightly more toxic than lead arsenate, and that barium fluosilicate and sodium aluminum fluoride were only slightly less effective and promising. Nicotine tannate, a sulfur—carbon disulfide emulsion, and a zinc sulfate—lime—derris mixture were failures in this test.

Biology and Control of the Apple Leaf-Curling Midge. (W. D. Whitcomb, Waltham.) The apple leaf-curling midge, tentatively determined as *Dasyneura mali* Kieffer, which has apparently been introduced from Europe, is now established in northeastern Massachusetts and southeastern New Hampshire. It was first observed in this country in 1928 but previous to 1933 was not known to be present outside of the town of Ipswich. Recent reports, however, indicate

that this midge has been observed but not identified at other points in the infested area during the last five years. The known infested area now covers about 1,000 square miles extending from Melrose, Massachusetts, westerly to Westford, Massachusetts, and northerly to Durham and Rye, New Hampshire. Several of the largest commercial orchards in eastern New England are now infested.

Injury is identified by the presence of tightly rolled leaves on the tips of branches and on water sprouts. The leaves are rolled from the underside upward toward the midvein and parallel to it. In heavily infested specimens the entire leaf forms two tight rolls. All varieties of apples grown in the orchards under observation were infested, but Baldwin, Delicious, and McIntosh appeared most susceptible, while Wealthy was almost immune. The growth of nursery trees and grafts is noticeably delayed and stunted by the activity of this midge, but on bearing trees the size, color, and abundance of fruit were not conspicuously affected during the present season.

There appear to be four generations annually, the first midges emerging about June 1, and requiring approximately 5 weeks to complete their life cycle. The abundance of the third and fourth generations depends on the number of water sprouts available. The eggs, which are laid on the unfolding leaves of terminal growth or water sprouts, hatch in 3 to 5 days, and the tiny white maggots feed for about 20 days within the tightly rolled leaves. When mature, the maggots are bright orange in color and usually fall to the ground where they spin a small white cocoon just beneath the surface of the soil. Pupation requires 13 to 18 days.

On water sprouts the majority of the infested leaves turn black and fall after the maggots have left them, but on terminal shoots many of the rolled leaves remain throughout the season.

Two natural enemies, a predatory bug and a parasitic hymenopteron, were reared from leaves infested by the midge, and promise to aid in controlling this pest.

Biology and Control of the Carrot Rust Fly. (W. D. Whitcomb, Waltham.) As in the two previous seasons, field infestation by the first generation of the carrot rust fly was negligible, and untreated carrots as well as those receiving insecticide applications were practically free from injury. The only infested carrots were found where the plants were watered daily during the oviposition period by overhead irrigation, and only 3 per cent of these were infested.

Injury by the second generation reached 26 per cent in the untreated plot and was greatest in the plot receiving overhead irrigation, where 32 per cent were infested. This further demonstrates the previously reported theory that cool, damp soil is favorable to this pest.

Of the dust treatments, which were applied July 31, August 7 and 14, and September 5 and 12, naphthalene was most efficient, with 98 per cent clean carrots. Soot and two dusts containing derris gave 90+ per cent control, and tobacco and two dusts containing mercury gave 80+ per cent control. Kainit was quite effective, but killed many seedling carrots and caused a poor yield. The treatment of seed with calomel or corrosive sublimate combined with gypsum in varying quantities reduced injury 10 to 15 per cent, but the results were not consistent with the amount of mercury used. Seed treated with pure calomel yielded 92 per cent clean carrots.

Adaptability of Cryptolaemus to Control of Mealybugs in the Greenhouse. (W. D. Whitcomb, Waltham.) The Australian Mealybug Destroyer, *Crypto-*

laemus montrouzieri Muls., can be secured from California at a very reasonable cost. The adult beetles are shipped by air mail and several shipments have been received in Massachusetts in good condition except during extremely unfavorable weather in winter. Both adult and larval stages of this ladybug feed on the greenhouse mealybug.

In the greenhouses at the Waltham Field Station extremely heavy infestations of mealybugs on gardenias have twice been satisfactorily controlled by liberating *Cryptolaemus* beetles at the rate of about 1 beetle per plant. When the beetles were liberated in January, the mealybugs were under control about 60 days later. When the beetles were liberated in August, perfect control of a most severe infestation was accomplished in 30 days.

Preliminary studies of the relation of temperature to the development of *Cryptolaemus* indicate that temperatures of 70° or above are desirable for efficient activity. It required four times as long for eggs to hatch and pupation to be completed at 60° F. as at 80°, indicating that these beetles will not thrive at low temperatures. Isolated pairs lived four months at average greenhouse winter temperatures and laid eggs intermittently throughout their whole life. The maximum number of eggs laid by one paired female was 107. The estimated increase from one generation in the greenhouse was 600 per cent.

Naphthalene and Similar Materials as Greenhouse Fumigants. (W. D. Whitcomb, Waltham.) Experimental fumigations of chrysanthemums with naphthalene have continued to indicate that this crop cannot safely withstand this treatment. Injury is usually shown by blindness or deformed bud development, and a varietal susceptibility is apparent. Major Bonnafon, Friendly Rival, and Halliday are among the varieties most susceptible to naphthalene blindness.

It was also demonstrated that the fumes discharged during the first two hours of a fumigation are largely adsorbed by the plants, soil, and equipment, so that the effect on red spider is negligible until after an exposure of three hours or longer.

Experiments with two commercial liquid fumigants in which the toxic benzene-ring products are dissolved in a non-injurious solvent have shown them to be effective for controlling red spider. Unlike crystal naphthalene, these fumigants do not become injurious at the minimum temperature for growing greenhouse plants, although their efficiency is decreased below 60° F. Most varieties of plants which tolerate naphthalene fumes will tolerate these materials, but cucumbers have been severely injured in all experiments.

Control of Red Spider on Greenhouse Crops. (W. D. Whitcomb, Waltham.) Preliminary studies on the relation of temperature to the effectiveness of some common commercial preparations used for combating red spider in the greenhouse indicate that this factor exerts an important influence.

On potted carnation plants an alcoholic extract of pyrethrum and soap gave 34 per cent greater kill of red spider at 60° F. than at 80°, and a 24 per cent greater kill when additional soap was added. Another pyrethrum extract with additional soap was 23 per cent more effective at 60° F. than at 80°. On the other hand, a selenium preparation was 49 per cent more effective at 80° F. than at 60°, while the effectiveness of a sulfur–carbon disulfide emulsion was not influenced by temperature.

DEPARTMENT OF FARM MANAGEMENT

R. L. Mighell in Charge

Enterprise Relationships and Farm Organization on Selected Dairy Farms in Massachusetts. (R. L. Mighell.) This study is concerned with the economics of the combinations of farm enterprises and of cost factors within each enterprise. Research along the latter line has taken the form of replanning labor routine and equipment for the most economical and efficient performance of regular daily tasks on dairy farms. In cooperation with W. C. Harrington, of the Agricultural Engineering Department, typical barn plans for 10-, 20-, and 30-cow capacities are being studied from the standpoint of efficient utilization of labor. As a preliminary step in this study an imaginary man is conceived of as doing imaginary chores, in a number of imaginary barns. Each imaginary barn is represented by a blueprint and as the chores are performed on paper, distances are measured, time is estimated, and other considerations of convenience are studied. As a final step, the most hopeful arrangements are checked in actual barns under real conditions. A number of interesting tentative conclusions have already been reached. For example, facing cows out proved to be usually more economical in terms of time and distance than facing cows in, contrary to a widely prevalent belief.

Another part of this project which is now being emphasized is a study of the economics of pasture improvement. This problem is one of finding the most profitable combination of enterprises and of cost factors such as fertilizer and labor. The study is being developed by using the budget method with typical cases representing conditions under which pasture improvement should or should not be recommended. An attempt is being made to develop a workable plan or method of approach which the individual dairyman can use in solving the problem for his own case.

Labor Saving Methods and Technique on Vegetable Farms. (R. L. Mighell and R. H. Barrett.) This study represents one of the first attempts in the United States to apply the so-called "Taylor System" of scientific management and time and motion study to agriculture. During 1933 a careful, intensive study has been made of labor-saving technique and equipment for asparagus, one of the important vegetable crops in Massachusetts. Supervised records, motion pictures, and close study and observation of typical farm set-ups, and of suggested changes have yielded significant results. In one important asparagus area a complete change in the type of asparagus bunching equipment and technique has been recommended as a result of the study. This change is now being adopted by growers in this area, with considerable saving in time and effort devoted to the task of bunching.

Economical Use of Labor in Silage Production on Dairy Farms. (R. L. Mighell and R. H. Barrett.) Continuing an intensive study of various types of wagons used in filling silo, initiated in 1932, motion pictures and time records were taken in September and October 1933. The time and motion records show clearly that the low down wagon saves an immense amount of human time and effort on such tasks as silo filling. The underslung type of low down wagon is apparently the simplest and easiest to make, and can be easily constructed by any farmer. Dump carts and other high wagons still in use by many New England farmers are very wasteful of time and energy both in loading and unloading.

Tests and observations on a few farms indicate that a mowing machine with a 5-foot cutter bar may prove very satisfactory for cutting silage corn in the field.

Nearly every dairy farmer has a mowing machine anyway, and in cases where the silage corn acreage is not sufficient to justify the purchase of a binder, the mower may prove to be the most economical method of harvesting.

FEED CONTROL SERVICE

Philip H. Smith in Charge

The Feed Control Service comprises not only feed inspection, but several other activities, as listed below:

Feed Control (General Laws, 1920, Chapter 94)
Seed Control (General Laws, 1927, Chapter 94)
Dairy Law (General Laws, 1920, Chapter 94)
Advanced Registry Testing
Miscellaneous Work

Feed Control. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski, F. A. McLaughlin, J. T. Howard.) During the fiscal year, 1,649 samples of feeding stuffs were officially collected and examined in the control laboratories. The results show that at least 97.7 per cent of the samples collected varied less than 1 per cent from stated guarantees in protein, fat and fiber content. The gross receipts from the registration of feeding stuffs in 1933 (calendar year) were $20,860, derived from 1,043 brands at $20 each.

Seed Control. (P. H. Smith, F. A. McLaughlin, Margaret E. Nagle.) From October 1, 1932, to October 1, 1933, the Seed Testing Laboratory analyzed 1188 seed samples, 507 of which were collected by the State Department of Agriculture, 180 submitted by dealers and farmers and 191 by the Rhode Island Department of Agriculture, 266 purchased from wholesalers for special tests, and the remaining 44 accounted for by germination tests of ingredients of grass seed mixtures.

	Massachusetts Official	Massachusetts Non-official	Rhode Island	Total
Purity analysis only	38	28	36	102
Laboratory germinations	323	419	3	745
Field germination	0	(266)*	0	...
Purity and germination	146	43	152	341
	507	490	191	1188
Field crops	26	26	25	77
Forage crops	158	121	164	443
Vegetables	323	334	2	659
Flower seeds	0	3	0	3
Tree seeds	0	6	0	6
	507	490	191	1188

*266 field tests are duplications of laboratory tests, portions of the same samples being used.

Field tests to determine trueness to type were again conducted in conjunction with the Department of Vegetable Gardening, which tested 266 samples of sweet corn.

Dairy Law. (P. H. Smith, J. T. Howard, H. L. Allen.) During the year ending December 1, 1933, 6,334 pieces of Babcock glassware were tested. Condemned glassware consisted of three milk-test bottles and one pipette. One hundred and five certificates of proficiency were awarded.

One hundred and ninety-four creameries, milk depots and milk inspectors' laboratories were visited in order to check methods and pass upon equipment in use. As a result of this inspection, three machines were condemned, and repairs were ordered on seventeen. Seven plants were re-inspected to approve repairs. Special investigations were made at nine plants.

Advanced Registry Testing. (P. H. Smith.) Advanced registry testing has been supervised by this department since its beginning in 1902. There are now on yearly test 328 cows located on 51 different farms. This does not include the herd tests where all animals in each herd are placed on test. Of these there are twenty-one, seven of which are supervised by men sent out from this office and fourteen by cow-test association supervisors.

Miscellaneous Work. (P. H. Smith, A. F. Spelman, J. W. Kuzmeski.) Numerous analyses have been made for residents of the State and other departments of the college.

Summary of Miscellaneous Work, 1933

Materials sent in:	
Milk and cream, butterfat only	182
Milk, solids and fat	3
Ice cream	7
Feeds, from farmers and dealers	80
Feeds, from State Institutions	121
For other departments of Experiment Station and College	
Milk, for butterfat	309
Dry matter, forage crops	2,235
Complete fodder analyses	84
Dry matter and nitrogen	94

FERTILIZER CONTROL SERVICE

H. D. Haskins in Charge

Fertilizer Inspection. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Records for the year show that 144 firms have registered for sale in the State of Massachusetts 495 brands of mixed fertilizer and fertilizing materials and 40 brands of agricultural lime and gypsum. The following summary shows the character of these substances, as well as statistics with reference to their inspection.

During ten weeks following April 1, four experienced men employed to draw samples for inspection purposes sampled 19,152 sacks or containers, representing 7,751 tons of material; 875 agents were visited.

	Brands Registered	Brands Collected	Samples Collected	Number of Analyses	Number of Determinations*
Mixed fertilizers	301	285	1,051	441	5,761
Ground bone, tankage and fish	53	51	152	61	294
Nitrogen products, organic and mineral	51	45	208	109	265
Phosphoric acid products	22	21	95	29	116
Potash products	10	10	58	17	44
Dried pulverized natural manures	31	30	97	32	216
Nitrate of potash	4	4	8	5	20
Miscellaneous	28	28	25	16	116
Lime products	40	40	65	41	351
Totals	540	514	1,759	751	7,183

*Not counting check tests or repeats, which amount to more than 1,000.

During the period July 1, 1932, to July 1, 1933, the tonnage of fertilizer and plant food sold in Massachusetts was as follows:

	Fertilizer (Tons)	Plant Food Elements (Tons) Nitrogen	Available Phosphoric Acid	Potash
Mixed fertilizers	37,076	1,845	3,078	2,408
Unmixed fertilizer chemicals and materials	16,451	1,187	1,343	400
Pulverized natural manures	1,443	31	21	40
Totals	54,970	3,063	4,442	2,848

Full details of the fertilizer and lime inspection will be found in Bulletins 69 and 71, Control Series.

Miscellaneous Analytical and Diagnostic Work. (H. D. Haskins, H. R. DeRose, A. F. Spelman, J. W. Kuzmeski.) Chemical investigations of a cooperative nature have been carried on, as has been the usual custom, with other departments of the institution, the Waltham Field Station, County Agents, etc. The character and extent of this work is shown from the following summary:

Artificial manures (nitrogen studies)	87	Cured hay	35
By-product fertilizers	3	Lead arsenate	1
Carnation blooms	2	Lime products	2
Citron	2	Manures	2
Complete fertilizers, home mixed and officially collected	17	Miscellaneous	2
Dried turnips	2	Peat products	5
Fertilizer chemicals	5	Tobacco soils	5
		Fish meal	5
		Greenhouse soils	2

The chemical work of the department has also included service to farm organizations, State institutions, community interests, as well as to individuals interested in agriculture. Reports in all cases have included interpretations and advice with reference to the problems involved. This group includes the following materials:

Agricultural lime products	9	Manures, pulverized	3
Ashes, cotton hull and incinerator	4	Manufacturers' by-products	11
Complete fertilizers	32	Miscellaneous	3
Fertilizer chemicals and unmixed materials	14	Peat products	14
Insecticides and fungicides	4	Stomach contents for mineral poisons	3
		Soils	52

As in the past, contact and cooperation have been maintained with the Association of Official Agricultural Chemists of North America.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) The study of rust resistance in snapdragons has progressed to the F_3 generation. Succeeding generations have resulted in reduction in hybrid vigor due to continued inbreeding. This has been manifested by a decrease in size of individual flowers and height of plants. Resistance to rust in the different strains in the F_3 generation has varied from 75 to 90 per cent, and in one strain to 100 per cent. In most strains yellow and white colors have bred 100 per cent pure in the F_3 generation. Resistant plants from the F_1 generation have maintained their resistance, even under field conditions, for three years.

Resistance in all cases observed appears to be complete, with practically no partial resistance. It would appear from data collected that resistance may be linked to some factor since there is a tendency for resistance and white color to stay together a greater number of times than resistance with yellow. Further study will be necessary to prove definitely any color linkage for resistance. A brief paper on this work was presented at the meetings of the American Society for Horticultural Science in 1933.

Study of the Effect of Plant Nutrients on Carnations Under Glass. (Harold E. White, Waltham.) When calurea, Cal-Nitro, ammonium sulfate, urea, calcium nitrate, and sodium nitrate were used as nitrogen sources, using a 4-12-4 as a basic fertilizer, the calurea and Cal-Nitro plots ranked first in production over the other materials. This rating has been observed for two years on experimental plots. Such results under experimental conditions would indicate that a combination of ammonia and nitrate nitrogen is preferable to straight nitrate sources.

Plots receiving no phosphorus produced six less flowers per square foot, whereas those receiving no potash produced eight less flowers per square foot. Plots receiving all the fertilizer elements as a complete fertilizer produced only two flowers less per square foot than plots receiving all the potash and phosphate prior to planting. Experimentally the difference is not great, but from a commercial standpoint it might be significant.

When bone meal was used as a source of phosphorus in comparison with superphosphate, the production was lowered six flowers per square foot. Nitrophoska, used as a partial source of phosphorus in combination with superphosphate, resulted in no great difference.

Fertilizer studies with roses have been discontinued due to lack of greenhouse space in which to grow this crop properly.

Varietal and Cultural Observations on China Asters. (Harold E. White, Waltham.) Some 60 strains of asters were grown in the field for observation of the behavior of wilt-resistant strains under New England conditions. Plantings were made in soil where two years before aster wilt was quite prevalent but even though non-resistant strains were included, wilt was practically nil in the 1933 plantings. Aster yellows was unusually severe—equally so on all strains with the exception of Queen of the Market which, although showing decided symptoms of yellows, was less severely affected by the disease than the late varieties. One explanation, other than by a resistance factor, might be on the basis that this variety carries far less foliage than the other strains, thus offering less feeding area for leafhoppers. One plant was found which showed probably inherited resistance. Selections were made for further study on yellows resistance.

The standard aster cloth, 22 x 22 threads per square inch, used for commercial culture of china asters would appear to be better than heavier grades. Three tents were used with the following results:

Cloth Used (Threads per square inch)	Light Transmitted (Per Cent)	Relative Production of Flowers
44 x 40	62	100
32 x 28	74	118
22 x 22	81	200

Chrysanthemums came into bloom 10 days earlier under cloth than under glass.

This experiment was made possible through the courtesy of the Lewis Manufacturing Company, Walpole, which supplied the cloth.

DEPARTMENT OF HOME ECONOMICS

Bernice Wait in Charge

The Comparative Value of Milk and Tomato for Supplementary Feeding in Elementary Schools. (B. Wait and M. V. Cowing.) For the preceding three years the children in a small consolidated rural school were given a supplementary mid-morning feeding, at first of either milk or tomato and later of a combination of evaporated milk and tomato juice. This study has been continued for a fourth year by feeding the children of a control school to ascertain whether any results of the feeding which seemed apparent could be duplicated in this latter group. Insofar as it has been completed, the analysis of the data tends to confirm the observation that there was some, although not marked improvement in the general well-being of a majority of the children as a result of the feeding in both schools, whether of milk or tomato or both.

The Value of Evaporated Milk for School Food Service. (B. Wait and O. A. Merriam.) This project is similar in purpose and in method to the above. Throughout two school years the children of the first four grades of the school in a small mill village were given a mid-morning feeding of eight ounces of reconstituted evaporated milk daily. The general condition of these children at the beginning and the end of the school year was determined by medical and dental examinations, and their growth, school progress, school attendance, and incidence of colds during the school year were observed. These same observations were

also made of a control group of children of the same grades in a school in a neighboring village. The control group was fed this year. As in the project above, insofar as the analysis has been completed, the data seem to indicate some improvement in the general well-being of the children in the experimental groups.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

W. W. Chenoweth in Charge

Technological Investigations and Nutritive Value of New England Fruit Products. (C. R. Fellers and J. A. Clague, with the assistance of G. G. Smith.) The vitamin C content of 17 varieties of apples has been determined by the guinea pig bio-assay method. A marked difference among varieties was noted: Baldwin and Northern Spy had the highest vitamin C values; Spitzenburg, Roxbury Russet, King, Gravenstein, Winesap, Rhode Island Greening, and Wealthy were intermediate; and Delicious, King David, Tolman Sweet, and McIntosh were very poor in this factor. The bio-assay of other varieties is being continued.

The spraying of apple trees with lead arsenate sprays had no effect on the vitamin C content of Baldwin apples. Previous preliminary data reported (*Proceedings of the American Society for Horticultural Science* 30 (1932): 93-97, 1933) on the distribution of vitamin C in the epidermis, flesh near the epidermis, and flesh near the core were confirmed. There is a definite increase in vitamin C in the outer layers of the flesh of apples.

Apple butter, boiled cider, and vinegar retained only traces of vitamin C. Regardless of the method of manufacture, apple sauce retained only 10 to 20 per cent of the original vitamin C content of the fruit.

The clarification of fresh cider was studied with a view to determining the most effective and inexpensive methods. Tests were made with enzyme preparations, gelatin-tannin precipitation, and filtration. Both the gelatin–tannin and the enzyme methods followed by filtration gave clear, sparkling ciders of high quality. Ten varieties of apples were studied for their cider making qualities, especially with respect to sugars, acids, pectin, and tannin.

Manufacture, Preservation, and Nutritive Value of Cranberry Products. (C. R. Fellers, J. A. Clague, and P. D. Isham.) About 10 additional varieties have been examined during the year for suitability for strained and whole sauce manufacture. Data have now been obtained on 60 varieties. Frozen cranberries were found to make good quality canned cranberry sauce, and several canners are now utilizing this information by freezing several thousand barrels annually for sauce manufacture during the off-season. Sauce made from such frozen berries is superior in color and quality to canned cranberry sauce which has been held in storage for several months.

The jelly strength tester developed by this department (*Industrial and Engineering Chemistry, Analytical Edition* 4:106, 1932) has been successfully used to determine the jelly strength of canned cranberry sauce. This is of importance because sauces showing strengths of less than 100 grams break down in shipment.

A new method of preparing candied cranberries has been developed. Briefly, the pricked fresh cranberries are placed in a 70 per cent sugar syrup in a vacuum pan and thoroughly exhausted. This impregnates the fruit with syrup. After drying, the fruit retains its excellent color and flavor and keeps well. Additional research has also been conducted on cranberry juice.

A very complete study of the vitamins of cranberries and cranberry products has been completed and published as Bulletin 296. The cranberry is a good source of vitamin C and contains small amounts of vitamin A.

Nutrition investigations of the effects of cranberries on urinary acidity and blood alkali reserve of human subjects have been completed and published in the *Journal of Nutrition* 6:455-463, 1933. Cranberries in the amounts normally eaten have no significant effect on urinary acidity or blood alkali reserve. Large doses increase the former and decrease the latter because of the presence of quinic and benzoic acids in the cranberry.

Intensive chemical work on the separation of the acids of the cranberry has not been entirely successful. No method has been found by which the quinic acid may be quantitatively extracted from cranberries. A chemical study including benzoic acid determination was made on ten leading varieties of cranberries. The benzoic acid varied from 0.035 to 0.095 per cent. A paper on this work has been accepted for publication by the *Journal of Plant Physiology.*

Utilization of Onions by Drying. (C. R. Fellers.) Cull Connecticut Valley onions were again successfully dried and manufactured into a dry white powder which retains to a remarkable degree the characteristic flavor of the fresh onion. A description of this product, method of manufacture, and uses was published in *Food Industries* in October 1933.

A start has been made on the study of onion pickling as a possible use of unmarketable onions. The small onions cure better in a 15 per cent salt brine than in weaker brines. Scarcely any lactic acid fermentation takes place in a 15 per cent brine, but the onions keep perfectly.

Nutritive Studies on Tomato Juices. (C. R. Fellers, J. A. Clague, B. Wait, and M. J. Mack.) Commercial canned or bottled tomato juices varied widely in their vitamin C content, some being only one third as valuable as others. These juices were utilized by the Home Economics Department in their research on the supplementary feeding of school children.

In general, homogenization of tomato juices had an adverse effect on their vitamin C content. However, the appearance was greatly improved because homogenized juices were very stable and the solids did not settle out.

Blueberry Investigations. (C. R. Fellers and P. D. Isham.) Blueberries were found to be good sources of vitamin C and to contain small quantities of vitamin A as well. Freezing did not injure the vitamins of the fruit. The canning tests were inconclusive in that some samples showed considerable vitamin C retention, while others did not. The results are published in the *Journal of Agricultural Research* 47:163-165, August 1933.

Feeding tests on human subjects showed that the ingestion of large amounts of blueberries had no effect on urinary acidity or blood alkali reserve. Likewise, they yielded no benzoic acid upon analysis.

Red Squill Research. (Robt. E. Buck and E. M. Mills.) This study is financed by the U. S. Biological Survey and has for its purpose the perfecting of red squill rat baits. Active laboratory work is under way on the preparation of alcohol, glycerol, and other squill extracts for use in combination with fish, meat, and cereals for rat baits.

Nutritive Value of Fish Meal. (M. M. Cleveland.) This research is financed by the Russia Cement Company of Gloucester. Comprehensive studies have been under way for nearly two years on the value of fish meals prepared in various

ways. As a sole source of protein for rats, fish meal from which the glue has been extracted is superior to unextracted fish meal. Similarly, the vacuum-dried meals gave better weight gains with rats than flame-dried. In cooperation with the Poultry Department, work is being conducted with both chicks and laying hens.

Effect of Fertilization on the Vitamin A and C Content of Asparagus. (C. R. Fellers, R. E. Young, and J. A. Clague.) Two crops of asparagus grown at the Waltham Field Station have now been assayed for vitamins A and C. While it is evident that fertilization has no major effect on the vitamin C content of asparagus, the results show a slight depressing effect due to high potassium and a moderate increase due to high nitrogen fertilization. No significant effect on vitamin A was found.

Canned asparagus retained fully the original vitamin A content, but lost from 60 to 80 per cent of the vitamin C. On the other hand, quick-frozen asparagus showed no vitamin losses after storage for several months. The results are now being prepared for publication.

Oven Canning. (W. W. Chenoweth, C. R. Fellers, and Pearl Haddock.) The use of electric and gas ovens for canning fruits, vegetables, and meats has been extensively advocated by range manufacturers and public utility representatives. Experimental results on a variety of foods, including a careful study of heat transfer in ovens and in jars of foods in the ovens, showed that a temperature of 212° to 213° F. is never exceeded. Oven canning is considered less likely to prevent spoilage in canned non-acid vegetables, meats, and marine products than the pressure-cooker or water-bath methods. Loss of liquid in the jars and scorching at the top and sides are two undesirable factors. The work is being continued.

Maple Products. (C. R. Fellers.) Molds may cause maple sugar to become soft and semi-liquid. The action was traced to the liberation of invertase by the mold mycelium. The invertase acts on the maple sugar (sucrose) and causes inversion. Losses due to this type of spoilage are very large, and no previous explanation was found in the literature. The degree of mold infection may be readily determined by making a direct microscopic Howard count of the maple sugar. This should be of great assistance to buyers of maple sugar in determining keeping quality of sugar and its suitability for syrup manufacture.

Two seasons' work have been completed on vitamin A and C determinations on maple sap, syrup, and sugar. Neither vitamin was present in significant amounts.

DEPARTMENT OF OLERICULTURE

Ralph A. Van Meter in Charge

Asparagus Investigations. (Robert E. Young, Waltham.)

Fertilizers. The yields of the asparagus fertilizer plots show an average increase of about 45 per cent over the yields of last year, with a much greater increase at Waltham and Concord than at Eastham. The quality of asparagus on all plots was higher than last year. In general the results obtained were about the same as last year.

In Waltham the most outstanding result was the increase in yield due to

applying the fertilizer May 1 instead of June 20, the usual time. The plots receiving just the nitrogen in May did not give this increase. Nitrate of potash and sulfate of potash did not produce as large yields as did muriate of potash. The kind and amount of nitrogen applied seem to have had very little effect upon the yield, except that cottonseed meal gave a considerable increase in yield both this year and last. The increase in yield due to increasing the amount of potash has been in direct ratio to the amount of potash applied. The application of a fertilizer mixture containing 18 per cent potash increased the yield, as compared with the crop produced with a fertilizer containing no potash, sufficiently to pay for the potash and allow a profit of approximately $30 per acre. The addition of extra phosphorus also gave a significant increase in yield.

The results at Concord were about the same as at Waltham, except that sulfate of ammonia caused a marked reduction in yield at Concord, while both cottonseed meal and a combination of guano and goat manure gave a great increase in yield.

The plots at Eastham still show the effect of organic matter, in the form of a crop of carrots turned under on half the field before the asparagus was planted. As a result, there is quite a variation between duplicate plots with the same treatment. The plots that have received no lime have been very materially reduced in yield. The plot receiving seaweed and superphosphate remains one of the high producing plots.

Varietal Improvement. Individual yield records were taken on 290 asparagus plant selections made by my predecessor. The number of stalks varied from 1 to 27 per plant, with a mean yield of 7.5 stalks. These records will be continued to determine the high yielding plants, which will then be removed to a seed production bed.

Effect of Fertilizers on Asparagus Plants Grown from Seed. The application of fertilizers to the seedbed in which asparagus seed was planted did not seem to have a harmful effect upon the asparagus plants. It was observed that there was a slight depressing effect when one of the fertilizer elements was either left out entirely or was present in extremely high amounts. This is the result for one year, and the experiment is being repeated.

Depth of Planting and Height of Cutting. A study of the yield records of this experiment shows that the plants have not yet reached their maximum production. The increase in productivity over 1931 was as follows:

	Per cent
Cut with only 4 inches green	44
Cut with 8 inches green	27.8
Cut with 12 inches green	29

The effect of the depth of planting remains about the same as last year. The deeper the roots are planted, the greater the mortality, which ranged from 11 per cent loss for the roots 2 inches deep to 31 per cent loss for the roots planted 8 inches deep.

Seed Improvement. (Robert E. Young, Waltham.) Samples of seed of the best strains of Horticultural bean grown in 1932 were distributed to a few selected growers this past season in order to determine the behavior of the beans when grown on different types of soil. The reports from these growers are very encouraging. Although selection will be continued, the seed stock now on hand

will be planted next year so that there may be a limited amount of seed available for 1935 plantings. It was observed that the seed stock was contaminated with some bacterial blight. Those who planted early reported some disease, while those who planted late, so that the plants matured in the cool fall, had no disease.

Considerable progress has been made in the improvement of the Waltham Beauty pepper. The plants are now more uniform in height, and the shape of the fruit is much improved. Performance on various types of soil was determined by placing samples of seed among the local growers. In general, the reports from these growers tend to indicate that it is better than any commercial strain available, although on several farms it has been observed that the pepper is not suited for light, high land where water is a limiting factor. Under these conditions the plants produced are very small and the yield small. Yield trials conducted at the Field Station this past season indicate that the Waltham Beauty will outyield the California Wonder by 138 bushels per acre; Harris Earliest by 293 bushels per acre; and World Beater by 99 bushels per acre.

Strains of Blue Hubbard squash now in the third and fourth generation were grown, and selfed specimens obtained. There is still some variation in the strain, indicating that it is not yet pure. Difficulty was experienced in getting some of the strains which had been selfed three or four times to set fruit, while commercial strains growing alongside selfed easily.

Selections of the Field Station Comet tomato grown in the field last season proved to be somewhat better than the former strain. This variety of tomato is being grown both in the greenhouse and on trellis in the field. Selections are being continued to free the strain of some recent outcrops of mosaic. The Boston Market Gardeners Association has produced a considerable quantity of seed from foundation stock supplied by the Field Station.

Past work on the Field Station Hutchinson carrot has been aimed mostly at uniformity and proper size, very little consideration being given to color. Selections are now in the greenhouse where it is planned to cross the strain with one having a deep orange color. The popularity of this variety is attested by the fact that the local Market Gardeners Association has had 1500 pounds of carrot seed grown for them from stock seed supplied by the Field Station.

Selection of the Wyman-Crosby beet is being continued to obtain greater uniformity, earliness, and better color. The present strain is fairly uniform and medium early, but rather poor in color. Attempts are being made to obtain a beet with smaller top and better internal color.

Selections were made of Bel-May lettuce that was planted in the greenhouse, to improve the bottom of the lettuce head. Many plants are inclined to be rather open, which shows the lettuce at a disadvantage as it is customary to market it with the bottom of the head up. Plants are now being grown from selections seeded last spring. An ample supply of Bel-May seed is available through a local farmers' organization.

Selections of Pascal celery that were seeded in the greenhouse in 1932 were grown this year and proved to be quite an improvement over the original commercial strain. Celery that is more uniform in height and has a long petiole is the type that is desired. Selections will be continued in connection with a celery storage project that is now under way.

DEPARTMENT OF PLANT AND ANIMAL CHEMISTRY

Edw. B. Holland in Charge

The Effect of Fertilizer and Cultural Treatment on the Composition of Havana Tobacco. (E. B. Holland and E. Bennett.) During the past five years numerous samples of different grades of cured and sweat leaf from the station plots have been analyzed and the data are being compiled for publication. The results indicate a distinct increase in nitrogenous compounds and decrease in ash of the web from the base of the plant upward, a noticeable effect of different amounts of applied nitrogen, and seasonal influences difficult to explain. The trend in other plant constituents—fat, fiber, and nitrogen-free extract compounds—in the grades is not as apparent.

Supplementary work on popular brands of smoking tobacco and of cigarettes has also been continued. A study of seasonal influences on the yield and percentage of the more remunerative grades has shown a distinct correlation for seven years with five cropping systems, but additional seasons will be necessary for confirmation.

Oil Sprays. (E. B. Holland.) Miscibles were prepared from special lubricating oils of three different manufacturers, with triethanolamine and oleic acid as the emulsifying agent. These oils had a Saybolt viscosity of about 100 but varied appreciably in density and percentage of unsulfonated residue. The main objective this season was to determine whether oils of somewhat higher content of unsaturated hydrocarbons would prove toxic to the fruit trees. The miscibles were applied at concentrations of 2 and 3 per cent of lubricating oils by weight and no ill effects were observed, but the infestation of European red mite was too slight to afford much evidence on control.

The number of emulsifying agents on the market is increasing rapidly and one commercial "base oil" mixed with three parts of spindle oil was tested in 2 and 3 per cent concentrations with satisfactory results. The use of such products makes the preparation of a miscible a relatively simple matter for any fruit producer.

Cooperative Investigations. (E. B. Holland.) An investigation of the causes and prevention of injury to greenhouse cucumber plants from spraying with various copper fungicides followed by hydrocyanic acid gas has been concluded and prepared for publication. The work was conducted by E. F. Guba at the Waltham Field Station.

A study of the effect of "dark center" on the composition of turnips has been reported. The initial changes are characterized by a substantial loss of sugars with an increase in protein, fiber, and ash. These analyses supplement the work of G. B. Snyder and R. W. Donaldson relative to the control of the disorder.

A large amount of analytical work was expended on ice cream stabilizers in connection with problems of the Dairy Department.

Nitrogen Fixation in the Presence of or as a Result of the Growth of Legumes versus Non-Legumes Under Certain Defined Agronomic Conditions. (F. W. Morse.) The comparison of legumes with non-legumes was continued this year with alfalfa and barley. To prevent weeds overtopping alfalfa, the field was repeatedly harrowed up to July 20. On August 5 the field was sown with alfalfa and barley. The latter was at its full height October 10. A severe frost on October 25 stopped all further growth, and three days later the plants with nitrogen fertilizers were prostrate while those without it remained erect.

Synthetic nitrogen chemicals were substituted this season for the older forms and included calcium nitrate, leunaphos, and calurea. Barley on leunaphos was perceptibly the tallest. Alfalfa was plainly superior on the nitrogen fertilizers in comparison with the growth without them. Both alfalfa and barley were left uncut and the latter will be plowed under next spring.

The investigation now becomes a comparison of methods of synthesizing atmospheric nitrogen: soil organisms versus factory.

Some study has been made of the relations between rainfall and crop production during the years of this investigation. Especially marked is the difference between millets and soybeans in the ratio of dry matter to rainfall. Japanese barnyard millet and soybeans were both grown in 1926. The Japanese millet was again grown in 1930. Hungarian millet and soybeans were grown in 1932. The soybeans in 1926 reached the pod stage, but in 1932 were barely at the flowering stage.

Rainfall used in the calculations is limited to the period in which the crops occupied the land and may be considered as equivalent to irrigation, although irregularly distributed. The soil is practically saturated at the end of March. The rainfall during April and May was 4.81 inches in 1926, 4.75 inches in 1930, and 4.00 inches in 1932.

Dry Matter per Acre and Rainfall in Inches

Year	Crop	Date Sown	Date Harvested	Dry Matter Pounds	Rainfall Inches	Pounds per Inch
1926	Japanese millet	6/11	9/1	9195	9.24	995
1930	Japanese millet	6/12	8/7 to 21	7033	10.42	675
1932	Hungarian millet	6/1	8/12 and 15	5384	7.88	683
1926	Soybeans	5/25	9/17	3681	10.74	342
1932	Soybeans	6/1	8/12 and 15	4376	7.88	555

The weather records of the experiment station give the normal rainfall for April and May to be 6.90 inches and for June, July, and August, 12.11 inches.

Hungarian millet is a smaller variety than the Japanese barnyard millet, but in the somewhat dry season of 1932 it utilized the water as efficiently as the Japanese variety did in 1930.

The heavier rainfall in 1930 included two unusually severe showers in July that flattened the crop and hindered its subsequent growth.

Chemical Study of Cranberries. (F. W. Morse.) The study of quinic acid has been continued with the object of more accurately measuring the quantity present in the cranberry. A review of the cranberry investigations conducted by the experiment station was prepared, covering a period of 25 years.

A Study of the Availability of Soil Potash with the Object of Developing a System of Diagnosis for the Soils of the State. (F. W. Morse.) The soil surveys of this State having been completed and published by the United States Department of Agriculture, this project is now being closed with the completion of potash determinations in typical soils of some of the more widely distributed series. The availability of the soil potash must in general depend on the fineness of the soil particles exposed to the solvent action of the soil water. Potash minerals form the softer constituents of the principal rocks of the State, and were more finely ground by glacial action than the harder quartz. The clay and silt of the soils might be expected to contain a higher percentage of potash than would be found in the sands. In a large majority of the samples this has been found to be the case.

Ten representative soils contained an average of 75.4 per cent fine sands and 12.9 per cent silt-clay particles. The average percentages of potash were 1.71 in the sands and 2.08 in the silt-clay. The bulk of the soil potash is held in the sands. In 100 pounds of soil, the sands will contain 1.27 pounds potash and the silt-clay only .27 pound. But this average soil to the depth of six inches would contain about 4000 pounds per acre of potash in the silt-clay particles. The stronger loams of the State may need little potash.

Mineral Requirements for the Growth of Dairy Heifers. (J. G. Archibald and E. Bennett.) The second phase of this project involving a three-year study of phosphorus requirements has been completed and the results prepared for publication. The principal conclusion reached is that rations ordinarily fed to growing heifers often do not contain sufficient phosphorus for optimum growth.

Studies in the Chemistry of Pasture Grasses. (J. G. Archibald and E. Bennett.) Results of a survey of natural pastures in the five western counties of the State have been published in Bulletin 300.

Another year's data on the chemical composition of various species of grass have been secured. The analytical work on this season's samples is nearing completion and results for the three-year period will be ready for publication early in 1934. A second series of plots of single species of grass has been established this season on an entirely different type of soil and will be available for continuance of the study next season. The object of this second series is to ascertain, if possible, whether traits of chemical composition which have been characteristic of certain species thus far in the investigation will hold true on widely differing soil types.

Commencing next season the first series of plots will be used for investigation of the effect of fertilizers on the chemical composition of individual species. Thus far the grasses on these have been grown without the aid of fertilizer other than that residual in the soil.

DEPARTMENT OF POMOLOGY

F. C. Sears in Charge

The larger peach orchard of the Experiment Station was removed in the spring of 1933 and only a few trees in a variety block remain. The past winter was rather severe and fruit buds were badly killed on trees in sites subject to low temperatures.

The apple crop was large when one considers the rather heavy crop of 1932. This may be due to exceptionally favorable weather during and immediately following the blooming period. Air temperatures were unusually high and fair weather favorable to bee activity prevailed. These conditions were similar to those of 1930 when there was a very heavy crop.

The Interrelation of Stock and Scion in Apples. (J. K. Shaw.) Control of the main orchard was resumed by the Station after a year of operation by a private grower. These trees have not been doing well and crops have been small. Increasing the supply of nitrogen seemed to injure rather than to improve the condition of the trees. There was an apparent improvement in growth and appearance of the trees in two rows to which about 3 to 4 pounds per tree of muriate of potash was applied. Analysis of the ash from shoots of the present

summer's growth showed, in all cases, a distinctly higher potash content. These were the same two rows which received potash in 1931 with no apparent beneficial results. However, the potash was applied in that year to the freshly plowed surface, while in 1933 it was applied to the unplowed surface and harrowed in. These results suggest that in the former case the potash was fixed in the soil before the tree roots could take it up. These observations suggest that the leaf burn and general poor condition of the trees in this orchard may be due to lack of potash in the soil. The matter will be further investigated.

The younger orchard on Malling stocks continued to develop well. The yield of McIntosh and Wealthy on the more distinctly dwarfing stocks was small except for those on Stock 4, the Dutch Doucin. This may be due to injury to the root system from soil freezing during the winter. The root systems of these stocks is small and the anchorage of the stocks is not strong enough to prevent heaving. Trees on Dutch Doucin yield more than those on any other stock. There are at least two weaknesses of this stock: it is not as hardy to cold as may be desired, and the anchorage is not very good. The trees have thus far stood up well but they are located where they are not exposed to severe winds. This orchard was fertilized this year with calcium cyanamid applied about two weeks before bud break with good results.

Efforts to increase the supply of the Malling stocks were continued. A stock bed of about 1300 plants was established and about 1500 rooted layers were budded or are available for budding next spring. The supply of dwarfing stock in this country is very limited and efforts are planned to determine which of these dwarfing stocks are most desirable and to place them in the hands of nurserymen and stock growers.

Tree Characters of Fruit Varieties. (J. K. Shaw and A. P. French.) Efforts were continued to establish a nursery of cherry varieties with rather poor success. For some reason buds fail to take well on Mahaleb or Japanese flowering cherry stocks. This difficulty will have to be studied and overcome before variety studies can be made. It is felt that climatic or weather conditions here are not favorable.

Some further observations made in nurseries in connection with the usual certification work of the Massachusetts Fruit Growers Association's inspections of nurseries for trueness-to-name over a period of years show that, while the number of misnamed trees has been reduced to a very small precentage, new mixtures appear occasionally. These are detected at once and do not become a continuing trouble as in earlier years. Fruit growers run distinctly less risk of getting misnamed trees if they buy from nurseries that have been inspected for trueness-to-name.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) Breeding work was continued in the spring of 1933 and a good crop of pits was obtained. About 300 seedling peaches resulting from the breeding work of 1931 were set out in two blocks. As a result of the 1932 breeding work there are 2415 trees in the nursery to be set in the orchard in the spring of 1934. From among the seedlings resulting from the breeding work of 1928 a few of the best were selected and propagated. There are 97 trees in the nursery propagated from 13 of these seedlings. Some of these will be set in the orchard in the spring of 1934 for trial.

The Gold Drop variety has reniform foliar glands which is supposed to be a homozygous gland condition. Among 954 seedlings of Gold Drop, selfed, there appeared 213 or 22.3 per cent having globose glands (the heterozygous condition)

and very sharply serrated, wavy leaves, a character usually associated with eglandular leaves. At present no data are available to explain this behavior.

Effect of Pruning Bearing Trees. (J. K. Shaw and O. C. Roberts.) The two projects formerly listed as dealing with pruning bearing trees may be considered as one. Yields are not often reduced by light pruning but they may be if pruning is severe. The average size of fruits is often a little larger on pruned trees than on unpruned ones. Color of certain red varieties is likely to be improved by pruning, but improvement in pest control is generally small or absent. In the 40-year-old orchard much work has been required during the past two years to cut out dead and dying wood. It thus appears that bearing trees must be pruned sooner or later, for dead branches furnish an opportunity for decay to enter and threaten the life of the tree. It must be as well or better to cut out weak, shaded wood before it dies. All the pickers agree that picking is more difficult on the unpruned trees.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) The fertilizer treatment of this orchard was the same as in 1932. Two cultivated plots in this orchard which had had no fertilizer for twelve or more years received a complete fertilizer in 1932 and 1933. No significant increase in production appeared last year, but in 1933 these plots produced the largest crops since planting. The purpose has been to increase growth of cover crop and thus the organic matter in the soil. While the cover crops were somewhat better in 1933 there can be no great increase of organic matter yet. The fertilizer program will be continued to see if the complete fertilizer gives better results than are obtained on the plots receiving nitrogen only. The crop for the latter plots was small. The sod plot receiving nitrogen and potash showed for the first time an increased yield of Baldwins, while the superior yield of McIntosh was not maintained so well this year. Twigs of both Baldwin and McIntosh from this plot showed higher potash content than others from a similar plot fertilized with only nitrogen.

Results from this orchard under observation for twelve years suggest the inadequacy of both the sod–nitrogen program and continued cultivation with a cover crop sown in early July.

The plot in cultivation without fertilizer continued to give low yields though they have been larger than they were in the earlier years, probably due to increased size of the trees.

Comparison of Clover Sod and Grass in a Sod Mulch Orchard. (J. K. Shaw.) The effort to maintain a sod of white clover by fertilizing with potash, phosphorus, and lime has proved a failure in this orchard. For the past three years the grass has been allowed to grow all summer partly to avoid the expense of mowing and partly to see what would be the effect on the trees. This may have been the reason for the disappearance of white clover. There does not seem to be any marked injury to the trees but, as no direct comparisons can be made, it cannot be said that no harm has resulted.

These white clover plots were given an application of a complete fertilizer in 1933 the same as the other plots. This seems to have increased the production from these plots, while that from the plots which have had a complete fertilizer for the past 11 years was smaller than previously. This experiment will be redirected next year.

Tests of Different Amounts of Nitrate of Soda. (J. K. Shaw.) Following the revised plan of using a complete fertilizer with 10, 17½, and 25 pounds of

nitrate of soda per tree in the off-bearing year only, these trees were fertilized in 1933. The crop was larger than in 1931 but the lower yield in 1932, the on year, reduces the two-year average for 1932–1933 below that of the previous two-year period of 1930–1931. This may be because of the remarkably large crop of 1930. No marked improvement of color and quality has been noticed. The present fertilizer plan will be continued.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) The mulched plots have been continued as before with additional mulch as available. Enough has been applied to suppress most of the grass and weeds. The cultivated plots received 300 pounds of nitrate of soda per acre. The Wealthy trees on Doucin stocks were removed in the spring of 1933 leaving only the standard trees. The Doucin roots sprouted freely and they seem to be Malling No. 6, Rivers Nonsuch Paradise. Yields of both McIntosh and Wealthy were somewhat smaller than in 1931, the previous light-bearing year.

The Effects of Fertilizer Limitation on Fruit Plants. (J. K. Shaw.) Lime at the rate of about two tons per acre was applied to the limed ends of the plots. This raised the pH value of the soil to about 6.25, where it was while the previous crop of trees was grown. The acidity of the unlimed plots remains about as it has been in earlier years, a little below pH 5. In all cases where potash is used alone or in combination, the growth of the trees was greater on the limed plots; while the reverse was true on all other plots except on one of the unfertilized plots. Growth was nearly twice as large on the unlimed plots receiving nitrate of soda but no potash, as on the unlimed plots with the same fertilizer. The results are similar to those with the previous crop of trees planted about 1922 except the trees on the phosphorus–potash–lime plots, where the growth is less than with those on the limed, complete fertilizer plots. It seems clear that a combination of potash and lime is the only fertilizer to which fruit plants respond on this soil, which has had a fixed fertilizer treatment for over 40 years. When potash and lime are applied, it may be that the addition of nitrogen will give further improvement in growth.

Role of Potash and Lime in Fruit Tree Nutrition. (J. K. Shaw.) Owing to limited funds and man power this project was dormant during the past year. It will be resumed or terminated and the results published in the near future.

Effect of Potash and Lime on Apple Trees. (J. K. Shaw.) The filler trees of several varieties were removed in the spring of 1933 (except the McIntosh trees) leaving only the Wealthy trees. There appears to be no effect from the lime, but the trees receiving potash in addition to nitrogen gave much larger yields than those receiving nitrogen only. The twigs from the potash trees contained more potash than those not fertilized with potash. If this trend continues in future years we must conclude that the time has come when this orchard requires potash in addition to nitrogen. There is as yet no indication of any benefit from additions of phosphorus to the fertilizer applied. This orchard is in sod.

Study of Varieties of Tree Fruits. (J. K. Shaw and O. C. Roberts.) Observations on numerous new varieties of different fruits were continued. Results were similar to those given in the last report. Wright's Early plum seems to be a promising substitute for Red June. It is equally productive and far better in quality.

Several new varieties of apples from C. P. Close of the United States Department of Agriculture fruited for the first time. They are all early red apples of

about the season of Yellow Transparent, some a little earlier and some a little later. Several of them are very promising, and buds of the better one were set to grow trees for a more extended trial.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) This project is concerned with the effect, on fruit bud formation, of nitrogen applications at various times during the latter part of the growing season. The project was undertaken five years ago and changes have consisted chiefly in altering the planting plan to vary the number of plants per square foot.

No consistent effect on fruit bud formation has been found either when plants were grown in hills with ample room or in moderately filled matted rows; and no effect has been found either on a good strawberry soil or on a soil needing fertilization to grow grain crops satisfactorily.

A new bed was set in the spring of 1933 to note the effect on runner plants of varying ages. All plots are duplicated five times and all receive phosphorus and potassium.

Bud Mutation. (J. K. Shaw and W. H. Thies.) The collection of trees top-worked to various mutating strains of several varieties of apples was maintained but none have borne fruit. The "flat limbed" strain of Gravenstein apple has thus far produced only normal branches.

Storage of Apples Under Various Conditions. (O. C. Roberts cooperating with C. I. Gunness and W. R. Cole.) Two particular lines of investigation pertaining to the storage of apples have been undertaken as follows:

1. A study of the effect of humidity on the keeping quality of McIntosh and Baldwin apples at 32° and 45° F. This is a repetition of similar studies which have been carried on for two seasons previously. Indications suggest that a humidity of 80 to 85 per cent is adequate for the keeping of apples in cold storage, while 85 to 90 per cent is necessary in the air-cooled storage.

2. The storage of McIntosh apples above 32° F. It is a generally accepted fact that apples which are to be preserved in the fresh state for the maximum length of time should be placed in storage at 32° as soon as harvested and held at that temperature continuously throughout the storage life of the apples. At harvesting time the apples do not possess the quality and flavor which they later acquire if held at a temperature of 45° to 50°. A temperature of 32° modifies the ripening process to the extent that the apples fail to develop the most desirable eating qualities and thus are still "green" in flavor when removed from storage and offered to the consumer. This is particularly true of the McIntosh.

For two seasons experiments have been conducted to determine whether McIntosh apples can be kept satisfactorily by holding at temperatures of 40° to 50° for a period of two weeks and then decreasing the temperature until 32° is finally reached about the middle of November. These experiments have not been repeated a sufficient number of times to justify definite conclusions. However, present indications suggest that the following results may be expected:

(1) The flavor of the apples is decidedly improved.

(2) The apples can be held in good condition for the Christmas trade.

(3) If apples are to be held for a longer period, they should be stored at 32° continuously.

Tests of Various Spray Materials. (O. C. Roberts, cooperating with A. I. Bourne and O. C. Boyd.) Various spray materials, both insecticides and fungicides, have been tested in the field to determine their efficiency and safety to

the tree and fruit. Results for the past season will be found in the report of the Entomology Department.

Blueberry Culture. (J. S. Bailey.) In the spring of 1933 the plantation to be used for cultural studies was enlarged to about one-half acre. The observations on height of water table were continued. Propagation was continued to obtain more plants for experimental purposes. Birds took such a large portion of the crop that very few berries were harvested from the variety plantings.

In the spring of 1932 some cultural experiments were started using one-year-old blueberry plants in three-gallon earthenware crocks. By the middle of the summer of 1933 it was evident that the root systems of the plants were becoming crowded and therefore the experiment on these plants would have to be discontinued at the end of the season. This work indicated that under some conditions lime is not as toxic to blueberries as has been previously supposed.

Additional pot experiments were started in the spring of 1933. These pots were accidentally left out in a heavy rain for a short time. The soil in some of the pots became saturated with water and several plants died and several more were severely injured as a result of the wetting. The new growth that was produced on the injured plants had light yellow, unhealthy-looking leaves. This accident emphasises the importance of planting blueberries in a situation where the roots will not be in a water-logged soil during the growing season.

DEPARTMENT OF POULTRY HUSBANDRY

J. C. Graham in Charge

Broodiness in Poultry. (F. A. Hays.) Results in developing a non-broody and an intense broody line through nine generations from 1923 to 1931 have been published as Bulletin 301.

The present method of procedure in this project calls for the use of progeny-tested sires in the non-broody line together with aged females for breeding, to discover whether it is possible to completely eliminate broodiness. More data are also being collected on degree of broodiness together with a study of inherited factors concerned in degree of broodiness.

Breeding Poultry for Egg Production. (F. A. Hays and Ruby Sanborn.) The mean annual egg production of the last generation of birds was 238 eggs. The mortality in the laying houses was 19.34 per cent. This last generation was superior in egg production to any other generation produced, and the mortality rate was significantly lower than in the two preceding generations. Egg size is steadily increasing without reducing the number of eggs laid. Hatching dates were set three weeks earlier in 1933 in order to study the performance records of the birds when hatched earlier. Special attention is being given to the elimination of winter pause, also to the establishment of greater uniformity for clutch size and to increasing vigor as measured by mortality in families on the range and in the laying houses. An exhibition quality strain was introduced in 1929 which has been carried in part for exhibition quality and in part selected for characters affecting egg production.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) Data have been prepared under this project and published as follows: "The Significance of Length of Biological Laying Year in Production Breeding," Bulletin 298; "Crossing Production and Exhibition Rhode Island Reds," *American*

Naturalist 67: 539-548, 1933; "Characteristics of Non-Broody and Intense Broody Lines of Rhode Island Reds," Bulletin 301.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) In 1929 a line of highest quality exhibition Rhode Island Reds was obtained. In 1930 a cross was made using an exhibition male on production-bred females from the station flock. In 1931 reciprocal crosses were made together with F_1 x F_1 and F_1 x original parents. In 1932 the F_3 generation was produced and F_2 birds have been backcrossed to grandparental stock. Complete egg records have been kept on all females along with records of plumage color. The data are now being prepared for publication.

Determination of Genetic Laws Governing Results of Inbreeding. (F. A. Hays.) The fifth generation of inbred progeny was hatched in 1933 from the two remaining lines. Progeny have also been produced by crossing the two lines. Special attention is being given to the prepotency of inbred birds compared with the general flock bred for high fecundity.

Factors Affecting Egg Weight and Shell Character in Domestic Fowl. (F. A. Hays.) Three lines produced each year by females laying 52-, 57-, and 59-gram eggs, respectively, during December have been carried into the sixth generation. The last two generations (1932 and 1933) have come from females having the ability to lay 52-, 57-, and 59-gram eggs in November of the pullet year. Distinctive types of shell color and shell texture have appeared together with significant differences in egg weight when the three lines are reproduced year after year by mating the three lines of females to full brothers.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) Preliminary studies on rate of feathering in Rhode Island Red chicks were made in 1931, 1932, and 1933. In the spring of 1933, 3200 chicks were classified for feathering on the twelfth day and again at eight or nine weeks of age. Some evidence has been secured that autosomal genes may be concerned in rate of feathering in Rhode Island Reds along with a major sex-linked recessive for early feathering.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Elimination Law. (H. Van Roekel, K. L. Bullis, O. S. Flint, D. M. Yegian, and Miriam K. Clarke.) During the 1932-33 pullorum disease testing season, 301,000 blood samples were tested by the macroscopic tube agglutination method. This number represented 300,714 chickens and 286 fowl other than chickens in 338 flocks. Among the samples from chickens, 0.47 per cent were positive, the lowest percentage ever attained in this State. All of the flocks in two counties were classified as negative. In nine of the thirteen counties less than 1 per cent of positive tests were recorded. The number of non-reacting flocks was 276, approximately 82 per cent of the total flocks tested. Of these, 145 flocks were 100 per cent tested. These represent 145,420 birds, 48 per cent of the total number of birds tested. No reactors were detected among the turkeys, pheasants, ducks, geese, and guinea fowl which were tested on 12 farms. Chickens were tested on 9 of these farms and revealed infection in 5. Necropsies were performed on 70 birds for 40 flock owners.

Pullorum Disease Investigations. (H. Van Roekel, K. L. Bullis, O. S. Flint, D. M. Yegian, and Miriam K. Clarke.)

1. *Cause of Doubtful Reactions.* These reactions occur in many birds from which *S. pullorum* cannot be isolated. Antigens were prepared from members of the typhoid, paratyphoid, and dysentery groups of bacteria. Agglutination tests were conducted with 11 species of these groups, employing 20 positive, 20 negative, and 39 doubtful pullorum sera. The positive and doubtful sera produced reactions in the majority of the antigens, while the negative sera reacted mainly with the dysentery antigens. Agglutinin absorption tests in a few sera also indicated that the dysentery group probably was not associated with the doubtful pullorum reactions. Thirty-three negative and ten doubtful sera were tested with 33 single strain antigens, representing 12 species of the three groups. Results of these tests were similar to the previous tests. Twenty birds were inoculated with 20 strains of 11 species, representing the three groups. Sera from these birds were tested with the 33 single strain antigens. The tests indicated that by employing ordinary laboratory cultures the agglutination relationships of *S. pullorum*, *S. gallinarum*, *S. abortivo-equina*, *S. enteritidis*, *S. aertrycke*, and *E. typhi* were so close that the sera could not be differentiated by the agglutination method alone. The *S. suipestifer*, *S. schotmulleri*, and *Al. fecalis* sera could be differentiated. The dysentery sera could be differentiated from all the others, and within the group the Sonne and Flexner types reacted differently. Considerable variation in agglutinability was noted within each species.

2. *Infectivity of Droppings.* Twenty-five hens, negative to the tube agglutination test, were exposed to litter contaminated with fresh droppings from positive hens. The exposure consisted of approximately one pint of fresh droppings six days a week for 52 weeks. Up to the present time, two months after the litter contaminations ceased, there have been no positive reactions.

3. *Viability of S. pullorum.* The organism has been recovered from a dry piece of cloth after a period of 503 days. Part of this was reported in a Master's thesis by M. K. C.

Laboratory Service--Pathology. (K. L. Bullis and D. M. Yegian.) Personal calls at the laboratory were recorded 107 times. The number of cases handled was 366 and the number of specimens 1,116. Distribution of the specimens was as follows:—1,041 chickens, 26 turkeys, 20 rabbits, 9 quail, 6 pheasants, 5 sheep, 2 grouse, 2 guinea pigs, and 1 each of the following:—canary, cow, dog, hay, and pigeon. The diseases encountered most frequently were parasitism, so-called "range paralysis," pullorum disease, and tumors. Disturbances of the kidney and oviduct were found in a large number of specimens. Several cases of entero-hepatitis in chickens were recorded. Diagnoses of diseases which are believed to be rare in Massachusetts were:—fowl typhoid 4, fowl cholera 2, and 1 each of avian tuberculosis, intestinal capillaria, erythroleukosis, feather mites, paratyphoid in turkeys, and gape worms in quail. A fatal case of corynebacterium infection was diagnosed in a pullet. A search of the literature did not reveal a description of this organism.

Farm and Station Bang Disease. In assisting this project, the laboratory tested 850 blood samples by the standard tube agglutination method.

Infectious Laryngotracheitis Field Experiments. (C. S. Gibbs.) Approximately 11,000 chickens were vaccinated against infectious laryngotracheitis during the summer of 1933 under range conditions. An especially virulent strain

of virus was used in preparing the vaccine. This virus had been studied in the laboratory several months and was maintained in one-month-old chickens, which had also been reared under laboratory conditions since they were two days old. The chickens for the laboratory studies were all secured from a single poultryman, and were uniform in size, appearance, and resistance. The virus was not used in the field experiments as vaccine, unless it killed one-month-old chickens in five days. This arbitrary standard was necessary because laboratory tests indicated that any attenuation in the virulence of the virus might produce unsatisfactory vaccine.

A special technique was devised for restraining the birds and making the inoculations. In the field experiments the percentage of takes varied from 80 to 100 per cent, depending upon the age of the birds. As far as takes were concerned the most satisfactory results were secured with chickens three and four months of age. This period correlated with the age of greatest susceptibility in chickens inoculated intratracheally with fresh virus.

Up to the present it has not been definitely proved whether this correlation is real or apparent. Anyway, it was found that the number of successful takes fell off proportionally as the chickens were older or younger than three and four months. These variations may have been due to the fact that natural resistance of chickens to vacccination increased with age, while difficulties in inoculating the bursa of Fabricius and the cloaca increased with the smallness in size.

The vaccinated birds are being checked for cloacal and laryngotracheal carriers. The results of this part of the experimental study will be reported later.

Distribution and Epizootiology Studies of Infectious Laryngotracheitis. (C. S. Gibbs.) This study is being conducted jointly by the Department of Veterinary Science and County Agents. The object is to make a thorough investigation of the distribution and epizootiology of infectious laryngotracheitis in Massachusetts. It is hoped that this study will eventually lead to some practical methods of controlling the disease. As yet the information which has come in is meager, although it is sufficient to indicate that the disease is confined largely to the eastern part of the State, and some counties have more of it than others. Factors other than chronic carriers seem to be instrumental in the spread of the disease from endemic centers. Just what these factors are in each locality has not yet been determined. It is impossible to formulate satisfactory control measures until these factors are known and other field studies completed.

Further Studies on the Desiccation and Preservation of Infectious Laryngotracheitis Virus. (C. S. Gibbs.) Recent experiments in this laboratory have shown that the virus of infectious laryngotracheitis may be satisfactorily desiccated and preserved by filling a properly prepared desiccator with dry air. The air is dried by passing over anhydrous calcium chloride, and through alkaline pyragallol and sulfuric acid. The dry air is drawn into the desiccator by means of an ordinary water pressure pump.

This method of desiccating and preserving infectious laryngotracheitis virus offers no advantage over the modified Swift method, which has been in use in this laboratory for several years, except that a vacuum pump is unnecessary, and the cost of equipment reduced.

Avian Paralysis or Neurolymphomatosis. (C. S. Gibbs.) An apparent relation of lymphocytoma to neurolymphomatosis has been demonstrated in a systematic study of malignant growths and paralytic conditions in a flock of known history. In some of the cases under study the pathological cell involved in

lymphocytoma apparently metastasized into the nervous system, and in other cases the metastasis extended in the opposite direction, i. e., from the nervous system into adjacent tissues. Concurrent affections were ruled out because the tumorous growths appeared to be continuous in these cases. In other cases lymphocytomas and neurolymphomas were found to be sharply separated by parenchymatous organs, muscles, and nervous tissue. The only possible explanation of these malignant growths concurrently invading all tissues of the fowl as single entities is that they are either lymphocytomas or neurolymphomas of such invasiveness that all tissues are affected by them. If this explanation is correct, then lymphocytoma and neurolymphomatosis have the same pathological characteristics when invading the same tissues; and it follows that neurolymphomatosis is a disease of young birds, while lymphocytoma is a manifestation of the same disease in older birds ten months or more of age. However, in spite of the conclusiveness of the evidence presented by these histological studies of spontaneous cases, the exact relation between lymphocytoma and neurolymphomatosis awaits etiological confirmation.

In these studies neurolymphomatosis was rarely found associated with a leukemic state of the blood, such as occurs in erythroleukosis and myelogenous leukemia. Lymphocytoma was more often complicated by leukemia.

Lymphocytoma, neurolymphomatosis, and leukemia are apparently responsible for an excessive mortality in flocks in which they exist, and are quite beyond the power of the average poultryman to control. The object of this study is to find some practical method of control. The results thus far indicate that all of them are probably of an infectious nature and poultrymen may be able to control them by slaughtering all birds showing symptoms. The diagnostic service is available to poultrymen for the purpose of assisting in the diagnosis of these diseases.

Sexing Living Baby Chicks. (C. S. Gibbs.) A demonstration of sexing living baby chicks was put on at the Poultry Breeders' School this year (1933). Considerable interest was shown and the method may find some practical use in New England. Schools are being established on the Pacific Coast and in the Middle West for the determination of sex in living baby chicks, and New England pountrymen may be forced to sex their chicks in the future in order to hold their trade. Furthermore, it should be remembered that over-production is one of the Nation's greatest problems. Drastic steps are being taken by the more progressive industries under the direction of the government for the curtailment of production of those commodities of which there is a surplus. Chick sexing immediately offers a method of reducing the cockerel surplus and lowering the cost of pullet production, as well as simplifying disease control problems due to overcrowding.

WALTHAM FIELD STATION

(Waltham, Massachusetts)

Ray M. Koon in Charge

For reports on approved projects conducted at this Station, in addition to those listed under this caption, see reports of the Departments of Botany, Entomology, Floriculture, and Olericulture.

Along with its function as a research unit of the College, this Station has continued to develop and advance in its usefulness as a center of information because

of its proximity to a dense population of varied horticultural interests. During the year there have been recorded more than 2500 persons who have consulted members of the staff regarding troubles threatening their commercial enterprises or to request assistance with problems relating to amateur horticulture as it is practiced by the home gardener. Telephone inquiries have numbered 2765, or 640 more than last year. The requests for printed information have increased in the same proportion.

Over 1000 soil samples have been brought to the Field Station during the year. Soil deficiency tests have been made and recommendations offered.

The Boston Market Gardeners Association has continued to use the Station as headquarters for their monthly Executive Committee conferences and have contributed much in the way of suggestions for worth-while projects. The Field Station staff has, as usual, arranged the program of seven educational meetings which the Market Gardeners Association holds during the winter months.

The Fifteenth Annual Field Day was held on August 2 with over 900 farmers attending. Demonstrations, most of the variety trials, and special projects were planned with this day in view. Continued interest was shown by the visitors in the work of the Field Station. Firms selling anything helpful to vegetable or flower growers were invited to demonstrate their wares, and twenty were represented.

The Seventh Annual Celery, Second Bunched Carrot, and First Bell Pepper Contests were held.

The Plant House. (P. W. Dempsey.) Interest in the model plant houses at the Field Station, and in the plans available for distribution, has been maintained at about the same level during the past few years. The new type of hot water heater, made by a national concern, installed in the new plant house last winter has proved extremely satisfactory. With automatic draft control, it is efficient in its use of fuel; with return opening only three inches from floor line, no pit is necessary; and the first cost is exceptionally low. Fuel costs for operating both plant houses (each 10 x 30 feet) all winter were about the same ($75 each) in spite of considerable differences in the type of construction.

Electricity as a Source of Heat in the Hotbed and Propagating Bench. (P. W. Dempsey.) Interest in this project on the part of commercial growers seems to be almost at a standstill. This is primarily due to the natural hesitancy to adopt new methods and also to excessive operating costs in many parts of the State. Charges for current by different companies vary considerably, many asking a price that almost prohibits consideration of the use of electricity as a source of heat for these purposes. A few power companies are cooperating even to the extent of furnishing equipment and current for growers who are willing to experiment.

Results obtained at the Field Station in the benches and beds were similar to those of last year. These prove that the equipment is good and show that some practical uses for this ideal heat will be found before long.

Work will be continued especially along the line of propagating hardwood and softwood cuttings.

Vegetable Variety Trials. (P. W. Dempsey.) This year the sweet corn tests included over seventy strains. There was no outstanding strain or new variety of particular merit. Bacterial wilt attacked the trials for the first time and although all the varieties were affected the early maturing varieties which have received particular attention the past few years were especially diseased. The Spanish Gold variety was the only exception, showing considerable resistance.

The late maturing varieties were not affected seriously (most of them yielding 80 per cent or better), and the new hybrids and inbreds showed almost no indication of wilt. If the wilt increases in severity as it promises to, resistance will necessarily be an important factor in variety or strain selection in the future. Earliness and size of ear have held the stage for many years; the Golden Sunshine, Early Golden Market, Golden Gem, and other varieties have occupied the spotlight. Now it seems as though attention will be focused on top-crossed, hybrid, and inbred strains. Seedsmen and experiment station breeders have been producing superior crosses, especially for the canners, for several years. All of these have been late in maturing in the Field Station trials thus far. Now, however, it will be necessary to consider them and plans are under way for an extensive trial of all these new strains available in 1934.

Over a hundred strains of tomatoes were planted this year in the tomato trials. Interest in trellis tomatoes is exceptionally keen just now, so particular attention was paid to varieties for this purpose. Many crosses of the Comet variety, originally made by V. A. Tiedjens and carried on by R. E. Young, were included and showed considerable promise. Further crosses made by Young also show possibilities; one, especially, of the so-called Field Station Comet on Lloyd Forcing was particularly good. Most of the strains for staking, procured directly from commercial seedsmen, were not satisfactory. There was no outstanding variety or strain in the trials except those referred to of the Field Station Comet crosses.

As in the case of the sweet corn crop, the tomato crop of Massachusetts is also threatened by a serious disease, the late blight rot (*Phytophthera infestans*). This disease was reported as present in this State in 1905. From that time until 1932 no mention of it can be found in State records. Last year about 10 per cent of the tomato crop was affected, the disease causing trouble mainly on the late outdoor crop and greenhouse crop after September 5. In 1933 over nine-tenths of the crop was affected, many complaints being received as early as the middle of August. There seems to be little or no difference in the susceptibility of different varieties to the disease, the only means of prevention probably being thorough spraying or dusting with Bordeaux.

The Model Vegetable Garden. (P. W. Dempsey.) A vegetable garden 50 x 100 feet that would serve as a possible stimulus and model to visitors was started this year. Many and varied are the plans given in extension circulars and seed catalogs, but a close perusal will show discrepancies in dates, distances, and other factors. This garden was planted to obtain definite information under average conditions. No manure was used; the whole garden was plowed, harrowed, and fertilized at one time; possible succession crops were emphasized especially. Flowers were included to increase the interest of all members of the family. Seed was planted by hand. Rake and hoe were the only tools used. This demonstration will be repeated and records will be kept of the various costs.

Varieties of Small Fruits. (P. W. Dempsey.) So many inquiries have come to the Field Station concerning the culture and varieties of small fruits that it was thought worth while to start a small-fruit test plot in order to permit visitors to observe a few of the standard varieties and some of the promising new varieties under actual cultivation. A number of raspberry and strawberry varieties were set last spring as a beginning.

Control of Cabbage Maggot. (W. D. Whitcomb and H. A. Wilson.) To determine the number and time of applications of a 1-1000 solution of corrosive sublimate which is most economical and effective in controlling the cabbage

maggot, treatments were made at the rate of ½ cupful per plant on May 9 (when the first cabbage maggot eggs were found), May 16, May 23, and May 30. Fourteen plots were arranged so that all of the possible combinations from four applications were made. In the untreated plot 57 per cent of the plants were damaged by the maggot.

One application made on May 9 gave 98 per cent control and made on May 16 94 per cent control, but the latter plot yielded twice as many large or medium sized heads and seems preferable. Two applications gave perfect control except when the first application was delayed until May 23. The number of good sized heads was greater when the applications were made on May 9 and May 16, and these appear to be the most timely applications. Three and four applications also gave perfect control, but the yield was not sufficiently greater than where two applications were made, to warrant the additional labor and cost. In this planting, about 75 per cent of the plants yielded large or medium sized heads by June 26 if the maggot was satisfactorily controlled.

Three applications of dusts containing mercury also gave 98 to 100 per cent control when applied on May 9, 16, and 23. Applications from both sides of the row did not increase maggot control over application from one side, but the size of the heads was improved by the additional dust. Two commercial dusts containing derris or rotenone did not give satisfactory control of maggot, and tar paper discs were not satisfactory.

Ornamental Display and Test Gardens. (Harold E. White.) The ornamental display gardens were established at the Field Station in 1931 to permit the study of varietal reactions and to provide an opportunity for the public to observe the plants they may desire to grow commercially or with which to beautify their home environment. The response of the public to these gardens has far exceeded expectations. At present, the gardens contain approximately 100 varieties of iris, 80 varieties of peonies, 40 varieties of roses, 40 varieties of New England asters, 500 varieties of rockery plants, 400 varieties of miscellaneous perennials, and 50 varieties of shrubs. All this plant material has been supplied gratis and with eagerness by various nurserymen. In addition, the New England Gladiolus Society maintains a display plot of some 300 varieties of gladiolus. Each year, fifteen to twenty seedsmen supply seeds of the new introductions in annual flowers in return for which they receive a report as to the quality of these varieties. Future reports will be in the nature of observations on hardiness and habits of certain ornamentals.

Horticultural Schools. (Harold E. White.) These schools originated in 1931 for the purpose of providing florists with the latest cultural information derived particularly from research, and to offer a source of information for home gardeners who, because of necessity or preference, do their own gardening. The Florists Schools have been attended each year by between 200 and 300 florists. The first Home Gardeners School in 1931 for one day drew 700 persons which was a far greater number than could be adequately accommodated. In 1932 and 1933 the two-day Home Gardeners program attracted an attendance of 800. A considerable number attending have come from outside this State. Schools of this nature have now become a part of the regular activity of the leading colleges.

PUBLICATIONS

Bulletins

293 Annual Report for the Fiscal Year Ending November 30, 1932. 68 pp. March, 1933.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

294 Recreational and Forestry Uses of Land in Massachusetts. David Rozman. 20 pp. illus. January, 1933.

During the last few decades there has been a considerable decline in the land area under cultivation in the State of Massachusetts; and largely as a result of this abandonment of farm land, about one third of the total area in towns with a population of less than 10,000 is owned by non-residents. In towns situated on the Coast and in some inland towns, especially in Berkshire County, such land is utilized to a great extent for recreational purposes; but in most other areas, land owned by non-residents is represented by idle acres covered by brush and inferior woods The development of recreational uses in communities with a large area of idle land benefits the local population by providing a greater amount in tax receipts, a local market for agricultural products, and some employment for local people; yet in some cases lack of interest in local institutions and competition with the farmers for hired labor may be detrimental. However, even with the increase in recreational uses and part-time farming which may be expected with the increase in good roads, the greater part of this idle land will have to be used for the growth of trees. Already there is a considerable area in state and town forests and small areas held by various public organizations. Care should be taken in increasing these holdings to see that the areas taken are not likely to be needed for other developments, such as part-time farming and summer homes.

295 The Immunology of Infectious Laryngotracheitis. Charles S. Gibbs. 20 pp. illus. May, 1933.

In order to be acceptable to the majority of poultrymen, treatments for infectious laryngotracheitis must be cheap, easy to administer, and fairly effective. Intravenous and subcutaneous methods of stimulating immunity did not measure up to this standard, and are therefore not recommended for field practice. Under laboratory conditions, the inoculation of the bursa of Fabricius appears to be the most satisfactory method of immunizing birds against this disease. Only birds in the best of health are suitable for vaccination, which is best administered when the birds are between three and four months old. Carefully controlled experiments are needed to determine the practical value of this method of vaccination under range conditions as well as the duration of immunity in fowls in heavy production.

296 Effect of Manufacturing and Preserving Processes on the Vitamins of Cranberries. Paul D. Isham and Carl R. Fellers. 19 pp. illus. May, 1933.

Cranberries are an important crop in Massachusetts. Nearly all of them are processed in some way before they are consumed. This study was undertaken to determine the effect of various methods of processing on their nutritive value. Both fresh and frozen cranberries are a very good source of vitamin C, the minimum protective dose for young guinea pigs being 3.5 to 4.5 grams daily. Whole-fruit cranberry sauce retains approximately three fourths of the vitamin C of the fresh fruit; but strained sauce, evaporated cranberries, and cranberry juice are poor sources of this vitamin. A four months' storage period at 40° F. caused a loss of 20 per cent in vitamin C content. There is a small but definite amount of vitamin A in cranberries; but vitamins B, D, and G are either absent or present only in traces. The study showed that handling and manufacturing methods may greatly alter the nutritive value of cranberries and cranberry products.

297 The Effect of Certain Cropping Systems on the Yield and Quality of Havana Tobacco. A. B. Beaumont, M. E. Snell, and E. B. Holland. 28 pp. illus. June, 1933.

Several cropping systems for tobacco either used or suggested for the Connecticut Valley were compared and results for eight years, 1924-1931, are reported. These experiments present a rather convincing argument for the use of a moderate quantity of manure as a supplement to commercial fertilizer. The advantage from manure lies largely in its effect on quality. The use of red top cover comes second as a means of producing good quality of tobacco, and is a much more feasible cropping system for most Valley farmers on account of the scarcity of manure. The rotation experiments gave results which were quite unfavorable to tobacco, although in most cases the other crops were apparently benefited by having tobacco in the rotation. The cropping systems studied produced little or no change in the soil conditions. Continuous culture of tobacco without the plowing in of a cover crop caused the greatest increase in acidity, which was only 0.5 of a pH unit. The use of cover crops, the rotation, and manure tended to stabilize the reaction of the soil; and acidity was reduced only in one of the rotations where limestone was used.

298 The Significance of Length of Biological Laying Year in Production Breeding. F. A. Hays and Ruby Sanborn. 11 pp. illus. June, 1933.

High persistency has long been recognized as an important factor in breeding for egg production. In previous studies persistency has been considered only within the limits of the 365-day pullet laying year. In the study here reported, birds having the ability to lay continuously for more than 365 days were found to be superior for breeding purposes to those having a shorter laying year.

299 Shipping Massachusetts Apples to Out-of-State Markets. A. H. Lindsey and A. A. Brown. 27 pp. illus. October, 1933.

The development of apple orchards in New England and especially in Massachusetts has made it desirable for growers to find markets outside of the immediate production area. Information regarding transportation methods and costs was obtained from growers who have been shipping to New York markets. Transportation and terminal facilities are described for seven leading cities which might become profitable markets for Massachusetts apples, and the advantages and difficulties of each of them discussed.

300 Chemical Composition of Herbage from Massachusetts Pastures. J. G. Archibald and E. Bennett. 7 pp. October, 1933.

In general the herbage from pastures located on Becket loam and Stockbridge loam, two common soil types in Berkshire County, was superior to that from pastures in the counties farther east. It contained more protein and minerals and less fiber, and the quantity of grazing available was usually greater. All of the samples measured up quite well in protein content and were not unduly high in fiber; the amount of calcium ranged from fair to good; but there was quite a decided deficiency of phosphorus, particularly on the lighter, less drought-resistant soils and in the autumn samples.

301 Characteristics of Non-Broody and Intense Broody Lines of Rhode Island Reds. F. A. Hays. 12 pp. November, 1933.

Through the method of breeding followed, the percentage of non-broody individuals in the pullet year for the non-broody line has fluctuated rather widely from year to year, reaching a maximum of 92.31 per cent and a mean of 72.66 per cent for the nine-year period. For the broody line, the mean percentage of non-broody daughters was 20.46 per cent. The data show that degree of broodiness is inherited; also that the non-broody line was distinctly superior to the broody line from the standpoint of annual egg production.

302 Higher Aging Temperatures in the Manufacture of Ice Cream. W. S. Mueller and J. H. Frandsen. 16 pp. illus. November, 1933.

Aging at 68° F. for 2, 4, and 6 hours produced no measurable effect on bacterial growth, pH, or titratable acidity of a pasteurized ice cream mix. When an ice cream mix which contained the correct amount of gelatin for low temperature aging was aged for 4 hours at 68° F., excessive retardation of melting and a curdled appearance resulted. This objectionable melting condition can be corrected by reducing the gelatin content approximately one fourth.

303 Effect of Hydrocyanic Acid Gas on Cucumber Plants Previously Sprayed with Copper Fungicides. E. F. Guba and E. B. Holland. 16 pp. illus. December, 1933.

The control of fungous diseases and insect pests of cucumbers in greenhouses frequently requires the use of copper fungicides and hydrocyanic acid gas. Complete destruction of greenhouse cucumber plantings has occurred in Massachusetts in some instances from such treatment. The only copper sprays which did not cause injury when followed by hydrocyanic acid gas were commercial basic copper carbonates, basic copper sulfates, and non-staining ammoniacal copper sprays. If other copper fungicides are used, fumigation with hydrocyanic acid gas should precede the copper spray in order to avoid injury.

304 Secondary Milk Markets in Massachusetts in the Period of Falling Prices, 1930-1932. David Rozman. 20 pp. illus. December, 1933.

The bulletin deals with the analysis of marketing problems arising largely from changing conditions of the milk supply in secondary markets of Massachusetts, represented by Gardner, Attleboro, and Newburyport. The most disturbing factors for the maintenance of stability in the secondary markets were found to be the influx of outside milk and the increasing number of producers entering the distributing field. The attempt to maintain a stable price level in the small markets independently of the general market trend has generally met with little success. The average net price obtained by producers for their milk in the summer of 1932 was 4.1 cents per quart in Gardner, 6 cents in Attleboro, and 4.8 cents in Newburyport. The highest percentage spread between these and prevailing retail prices was in Gardner and the lowest in Newburyport. The milk marketing set-up prevailing in Newburyport, where most of the producers sell their milk to small dealers and distributors, largely their neighbors, was found to be the most economical for a small market.

Control Bulletins

67 Seed Inspection. F. A. McLaughlin and Margaret E. Nagle. 47 pp. February, 1933.

68 Thirteenth Annual Report on Eradication of Pullorum Disease in Massachusetts. The Poultry Disease Control Laboratory. 8 pp. August, 1933.

69 Inspection of Commercial Fertilizers. H. D. Haskins. 46 pp. November, 1933.

70 Inspection of Commercial Feedstuffs. Philip H. Smith. 58 pp. December, 1933.

71 Inspection of Agricultural Lime Products. H. D. Haskins. 8 pp. December, 1933.

Meteorological Reports

529 – 540, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. C. I. Gunness. 4 pp. each.

Reports of Investigation in Journals

(Numbered Contributions[1])

138 Nutritive Value of Cranberries. Carl R. Fellers. Amer. Jour. Pub. Health 23:13-18. January, 1933.

140 Bronchitis of Baby Chicks. Charles S. Gibbs. Poultry Sci. 12:46-48. January, 1933.

141 The Desiccation and Preservation of Infectious Laryngotracheitis Virus. Charles S. Gibbs. Jour. Bact. 25:245-251. March, 1933.

142 The Distribution of Nitrogen in Tobacco When the Supplies of Nitrogen and of Light Are Varied During the Growing Period. Walter S. Eisenmenger. Jour. Agr. Research 46:255-265. February 1, 1933.

143 Some Factors Affecting the Palatability of Pasture Plants. A. B. Beaumont, R. E. Stitt, and R. S. Snell. Jour. Amer. Soc. Agron. 25:123-128. February, 1933.

145 Studies of Bacterium Coli in Privately Owned Rural Water Supplies. Ralph L. France. Jour. Bact. 25:623-635. June, 1933.

148 Studies in the Food Requirement of Adolescent Girls: IV. The Mineral Intake of 38 Well-Nourished Girls 10 to 16 Years of Age. Bernice Wait and Lydia J. Roberts. Jour. Amer. Dietet. Assoc. 9:124-137. July, 1933.

150 Relation Between Body Weight and Age at Sexual Maturity in Rhode Island Red Pullets. F. A. Hays. Poultry Sci. 12:23-25. January, 1933.

151 Relation of Weight at Sexual Maturity to Annual Egg Production. F. A. Hays. Poultry Sci. 12:25-26. January, 1933.

152 "Suspected Mosaic" of the Strawberry. E. F. Guba. Phytopath. 23: 654-661. August, 1933.

153 Vitamin C Content of Baldwin Apples and Apple Products. C. R. Fellers, M. M. Cleveland, and J. A. Clague. Jour. Agr. Research 46:1039-1045. June 1, 1933.

154 The Influence of Legume versus Non-Legume Crops on the Microbiological Activities in the Soil: II. Nitrification and Cellulose Decomposition. James E. Fuller. Soil Sci. 35:485-491. June, 1933.

155 The Proper Supplementary Ration for Milking Cows on Fertilized Pasture. Richard C. Foley. Jour. Dairy Sci. 16:407-411. September, 1933.

158 Aging Effects on Gelatin Dispersions. W. S. Mueller. Indus. and Engin. Chem. 25:707. June, 1933.

159 Relation of Temperature to the Development of the Plum Curculio in Apples. W. D. Whitcomb. Jour. Econ. Ent. 26:415-419. April, 1933.

160 The Massachusetts Plan for the Eradication and Control of Infectious Laryngotracheitis. Charles S. Gibbs. Jour. Amer. Vet. Med. Assoc. 83 (N. S. 36): 214-217. August, 1933.

161 The Inheritance of Certain Characters in the Peach. J. S. Bailey and A. P. French. Amer. Soc. Hort. Sci. Proc. 1932:127-130. 1933.

162 Vitamin C Distribution in Baldwin and McIntosh Apples. C. R. Fellers, P. D. Isham, and G. G. Smith. Amer. Soc. Hort. Sci. Proc. 1932:93-97. 1933.

163 Assimilation of Fixed Nitrogen by Grasses and Clovers. A. B. Beaumont, W. S. Eisenmenger, and W. J. Moore, Jr. Jour. Agr. Research 47:495-503. October 1, 1933.

164 Filtrable Virus Carriers. Charles S. Gibbs. Jour. Infect. Diseases 53:169-174. September-October, 1933.

165 Vitamins C and A in Blueberries. C. R. Fellers and P. D. Isham. Jour. Agr. Research 47:163-165. August 1, 1933.

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Publication of this Document Approved by Commission on Administration and Finance

2500-4—'34. No. 983.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 306 January, 1934

Fertilizer Tests On An Important Pasture Soil Type

By A. B. Beaumont

In order that the results from previous investigations regarding the use of commercial fertilizers on permanent pastures might find more specific and wider application, the work was carried into other sections of the state for trial and demonstration on a different soil type. This bulletin presents results from that work.

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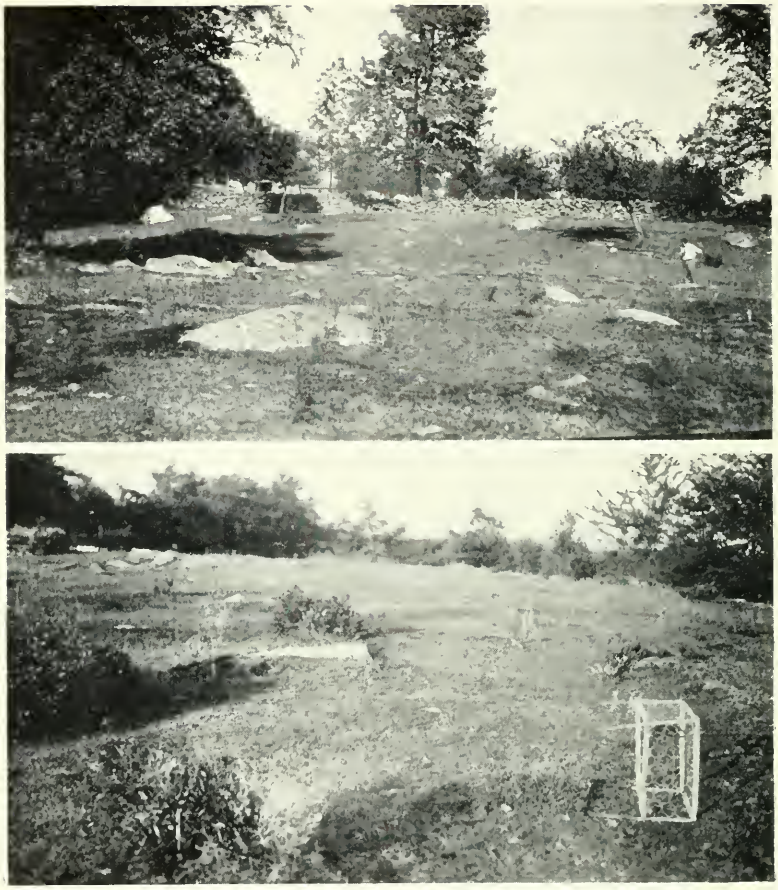

Figure 1. Two of the Experimental Fields in Worcester County, on Typical Gloucester Stony Fine Sandy Loam.
The sampling cage is shown in the lower photograph.

FERTILIZER TESTS ON AN IMPORTANT PASTURE SOIL TYPE[1]

By A. B. Beaumont, Professor of Agronomy

Introduction

In a previous bulletin(1) there were reported results of top-dressing permanent upland pastures with chemical fertilizers. Those experiments, conducted at or near the Experiment Station in Amherst, showed that the upland pasture soils tested responded to applications of lime, phosphoric acid, potash, and nitrogen. Nitrogen produced the greatest absolute and relative increases in yield, and was more effective when used with the other materials than when used alone. The character of the vegetation was changed by the fertilizer. Weeds were eliminated or markedly reduced. The presence of white clover was encouraged by the mineral treatment, particularly lime and potash, and the grasses by nitrogen.

In the present bulletin are given results of pasture experiments previously unreported. The purpose was to ascertain to what extent results obtained at Amherst were applicable to other soil types in the state. Inasmuch as nitrogen fertilizers did not figure prominently in the original experimental plan on account of the then comparatively high cost of nitrogen, it was decided to give this nutrient a more prominent place in the plan of these experiments. Accordingly, treatments of a nitrogen fertilizer alone and in certain combinations were included. As in the earlier experiments, Chilean nitrate of soda was the carrier of nitrogen used.

Location, Soil Types, and Flora of Experimental Fields

In the fall of 1929 ten experimental fields were selected[2] on Gloucester stony fine sandy loam, on typical dairy farms of Worcester County. The areas selected for the experiments had not been fertilized within recent years, so far as the records of the owners or operators of the farms indicated. The experimental fields were fairly well distributed over the county from north to south. Thus the experiments were located on the most extensive pasture soil type in the most extensive dairy district in Massachusetts.

The soils of the Gloucester series are important as pasture soils in the State as a whole, and together comprise 29 per cent of the land area of Worcester County. These soils consist of glacial till derived from granitic rocks, have a rolling to rough topography, good to excessive drainage, and good texture and structure, but usually contain so many large stones and boulders as to make tillage difficult. They are best adapted to pastures, orchards, or forests. See Tables 1, 2, and 7 for physical and chemical characteristics, and Figure 1 for

[1]Financial support of these experiments was given by the Chilean Nitrate of Soda Educational Bureau, whose co-operation is here gratefully acknowledged.

[2]Professor Ralph W. Donaldson, Extension Agronomist, assisted in selecting the sites of the experimental fields. His co-operation in the execution of the field work and the interpretation of results has been most helpful.

appearance of the Gloucester stony fine sandy loam, which in the tables is designated by the letter "W". Observations of the effect of fertilizer treatments were made on the ten experimental fields, and quantitative measurements of yields were secured on as many as six in any one season. Four of the fields were studied in detail.

TABLE 1.—MECHANICAL ANALYSIS* OF PASTURE SOILS

(Per cent of constituents)

Experiment	Total Sands (2—0.05 mm)	Silt (0.05—0.005 mm)	Clay (0.005 mm or less)	Total Colloids
W-1**	40	42	18	24
W-2	50	36	14	22
W-5	52	32	16	22
W-9	66	20	14	18
H-15	42	46	12	16

*According to hydrometer method of Bouyoucos.
**W=experiments in Worcester County.
H—15=Amherst pasture experiment.

TABLE 2.—LOSS ON IGNITION, ORGANIC MATTER, AND REACTION OF PASTURE SOILS

(Per cent oven-dry soils)

Experiment	Loss on Ignition	Organic Matter*	pH
W-1	8.29	5.44	5.2
W-2	8.21	5.91	4.9
W-5	8.06	5.06	5.0
W-9	6.01	4.09	4.9
H-15	6.84	4.44	4.7

*Per cent carbon ×1.724.

Another experiment was conducted on the Hobart farm in Amherst. The soil is classified as Cheshire fine sandy loam, stony phase, and has characteristics similar to those of Gloucester stony fine sandy loam, but contains more sedimentary rock material. Red sandstone fragments give the Cheshire soils a reddish brown or pink cast. This soil is designated as H-15 in the tables.

With the exception of experiment W-8, all the experimental fields in Worcester County had a fairly good sod to begin with. The flora consisted mainly of bent grasses, small amounts of Kentucky bluegrass and white Dutch clover, and varying proportions of weeds consisting of haircap moss (*Polytrichum commune* L.), running cinquefoil (*Potentilla canadensis* L.), hardhack (*Spiraea tomentosa* L.), sorrel (*Rumex acetosella* L.), poverty grass (*Danthonia spicata* (L.) Beauv.), another native grass (*Paspalum Muhlenbergii* Nash), bluets (*Houstonia caerulea* L.), a small reddish weed (*Hypericum gentianoides* (L.) BSP.), etc. On field W-8 the flora was mainly the weeds mentioned, with very little grass and with Juniper shrubs also present. This was by far the poorest field studied. The original vegetation of the Amherst field consisted mainly of haircap moss, with occasional plants of running cinquefoil, sorrel, and bent grasses.

Plan and Method of Experimentation

The Worcester County experiments were conducted on duplicated plots 1 rod square, laid out in the checkerboard fashion. The experimental field was not fenced, and dairy stock grazed the plots at will along with the rest of the pasture. Grass samples for determining growth response were obtained by hand clipping of areas protected from grazing by means of a wire cage designed by the writer. (Figure 1.) This cage was 2 ft. x 1.5 ft. x 9 in. and was made by covering a frame built of angle iron with 2-inch mesh chicken wire. Each time a clipping was made the cage was removed to a fresh, grazed spot within the plot. In this way, the condition of continuous grazing of the clipped area was approached. With the exception of 1930 when a dry August prevented normal late growth of grass, three cuttings were taken from each sampled plot.

The Amherst pasture plots were handled in a manner somewhat different from that just described. The dimensions of the original plots on this field were 10 ft. x 10 ft. Later these were subdivided into plots 5 ft. x 10 ft., one of which received minerals, and the other minerals plus sodium nitrate. The cows were excluded from the experimental field from the beginning of the growing season until about the first week of June, when the plots were sampled by the quadrat method. The cows were then allowed to graze the plots down to the customary level. Then they were excluded and the grass allowed to make sufficient growth for a second cutting, after which the plots were grazed for the rest of the pasture season. In this way normal pasture conditions were simulated, but not so well as in the Worcester County experiments.

The treatments were as follows:

Material	Key Letter	Pounds per Acre	
		Worcester	Amherst
Finely ground limestone	L	2400	1740*
Superphosphate (16% P_2O_5)	P	480	435
Muriate of potash (48-50% K_2O)	K	160	108
Chilean nitrate of soda (15.5-16% N)	N	160	193.5

*Amherst Experiment: 2L = 3480 3L = 10875
2P = 1740 3P = 5220
2K = 216 3K = 432

The Worcester experiments received all materials but the nitrate in the fall of 1929; the nitrate was applied in the spring of 1930, 1931, and 1932. The Amherst experiment received the non-nitrogenous materials in the spring of 1924 and 1929, and the nitrate in the spring of 1929, 1930, 1931, and 1932.

Weather Conditions

The mean annual precipitation at Amherst, Massachusetts, was 43.49 inches for the period 1889-1928. For the same period the mean total precipitation for the normal pasture season, which includes May, June, July, August, and September, was 19.53 inches. This varied from 3.5 inches to 4.3 inches per month. For the typical, well-drained, upland pasture soil of Massachusetts a minimum of about 3 inches of rain a month is required for good growth of grasses and clovers. If the total falls below 2 inches for any one month, a drouthy condition restrictive of growth usually results. This occurred in the late summer of 1930. If the

total rainfall exceeds 6 inches for any one month the beneficial effects of fertilizers, especially nitrogenous materials, are likely to be reduced. Trends in these directions are indicated particularly by the results from Worcester County. The total precipitation for the period May to September inclusive for the three years under consideration was as follows: 1930, 16.21 inches; 1931, 24.62 inches; 1932, 14.75 inches.

Presentation of the Results

Worcester Experiment

In Table 3 are the yield figures for the Worcester experiments. The mean increase over the check for each treatment is given in Table 4, with a comparison of four of the experiments from which the most data were secured.

TABLE 3.—YIELD FROM WORCESTER EXPERIMENTS

(Pounds dry matter per acre)

Experiment	Check	L	L, P	L, P, K	N	L, N	L, P, N	L, P, K, N
				1930—Two Cuttings				
W—1	884	1018	1136	1830	1872	....	....	2746
W—5	584	1180	998	1242	2208	....	....	2022
W—9	1178	2036	1638	2064	1430	....	....	2514
Mean	882	1411	1257	1712	1837	....	....	2427
				1931—Three Cuttings				
W—1	1245	1280	1082	1120	1088	1770	2077	2819
W—2	1414	1677	1638	1843	2192	2208	2074	1904
W—5	627	842	922	982	1030	1690	1798	2163
W—9	1347	1290	1939	1786	2173	2259	2099	1808
Mean	1158	1272	1395	1133	1621	1982	2012	2174
				1932—Three Cuttings				
W—1	989	1306	1216	1795	1421	2400	1792	3328
W—2	1011	1558	1443	1418	1789	2083	1997	1750
W—4	2198	2230	2813	3651	3424	3245	2778	2275
W—5	893	1005	1066	1261	867	1411	1229	1658
W—8	509	646	749	797	944	851	1168	986
W—9	1085	1152	1686	2646	1395	1661	2387	3373
Mean	1114	1316	1496	1928	1640	1942	1892	2228
Grand Mean	1051	1333	1383	1691	1699	1962	1952	2276

First, it may be noted that with the exception of phosphorus each additional nutrient produced some increase in yield, if the mean of all experiments for the three years is considered; that is, the fertilizer effects were mainly cumulative. If individual years and experiments are considered, it will be seen that there were some negative effects from phosphorus. These negative differences are probably within experimental error, which is admittedly high in this type of work. The mean increase due to phosphorus in both combinations was 20 pounds; to potassium 343 pounds; to nitrogen, alone and in combinations, 556 pounds; and to calcium in the form of lime, 230 pounds. Certain individual differences in response are discussed later.

TABLE 4.—MEAN INCREASE OVER CHECK, WORCESTER EXPERIMENTS

(Pounds dry matter per acre)

Treatment	All Experiments				1931 and 1932 Experiments			
	1930	1931	1932	Mean	W-1	W-2	W-5	W-9
L	529	114	202	282	176	405	164	5
L, P	375	237	382	331	32	328	234	597
L, P, K	830	275	814	640	341	418	362	995
N	955	463	526	648	138	478	189	568
L, N	...	824	828	826	968	933	741	744
L, P, N	...	854	778	816	818	823	754	1027
L, P, K, N	1545	1016	1114	1225	1457	615	1151	1375

Amherst Experiment

In Table 5 are presented the total yields of vegetation from the Amherst experiment for 1931 and 1932. The results are quite similar to those obtained from this experiment in 1929 and 1930 (Experiment C, Bulletin 281) with the following exceptions. Nitrogen alone was more effective than any other single element, but did not produce as much as the best combination of minerals. This improvement in the relative position of nitrogen in the last two years as compared with the first two, is probably due to cumulative effects of the sodium nitrate. Aside from any possible cumulative effect of nitrogen itself, there is a cumulative benefit due to the toxic effect of sodium nitrate on haircap moss, and probably a cumulative effect of sodium on the availability of phosphorus. These effects are discussed later.

TABLE 5.—TOTAL YIELD FROM THE AMHERST PASTURE EXPERIMENT

(Pounds dry matter per acre)

Treatment	1931		1932		Mean		Increase Over Check		Increase Due to N	Ratio No N:N
	No N	N	No N	N	No N	N	No N	N		
K	461	475	155	515	308	495	39	226	187	1:1.6
P	1539	1434	285	779	912	1107	643	838	195	1:1.2
L	1461	1530	251	1090	856	1310	587	1041	454	1:1.5
L, P	1581	1386	197	659	889	1023	620	754	134	1:1.2
P, K	621	1138	94	511	358	841	89	572	483	1:2.4
L, K	1657	1485	211	920	936	1203	667	934	267	1:1.3
L, P, K	1246	1787	267	645	757	1216	188	917	459	1:1.6
2K	294	989	405	1114	350	1052	81	783	702	1:3.0
2P	359	910	447	986	403	948	134	679	545	1:2.3
2L	706	1069	308	1184	507	1127	238	858	620	1:2.2
2L, 2P	865	985	839	963	837	974	568	705	137	1:1.2
2P, 2K	567	1386	314	1391	441	1389	172	1120	948	1:3.1
2L, 2K	692	936	619	1362	656	1149	387	880	493	1:1.7
2L, 2P, 2K	948	1374	778	2093	863	1188	591	919	325	1:1.4
3K	629	1210	283	1208	456	1209	187	910	753	1:2.6
3P	424	1093	234	1040	329	1067	60	798	738	1:3.2
3L	510	904	213	888	377	896	108	627	519	1:2.1
3L, 3P	888	1592	230	827	559	1210	290	941	651	1:2.2
3P, 3K	536	1158	186	533	361	816	92	577	485	1:2.3
3L, 3K	1069	1803	341	1011	705	1407	436	1138	702	1:2.0
3L, 3P, 3K	2045	2586	571	1012	1308	1799	1039	1530	491	1:1.1
Check	158	1119	380	1167	269	1143	....	874	874	1:4.2

Nitrogen and the minerals were mutually helpful in increasing yields. With the smaller amounts of minerals nitrogen increased yields about 50 per cent, while with the larger applications the yields were more than doubled. Calcium (in limestone), phosphorus, and potassium alone were generally beneficial, but the relative position of each in increasing yields is less certain than in the case of the Worcester experiments. These nutrients were decidedly more effective when applied in various combinations than when used singly. This is especially reflected in the botanical composition of the clippings.

In Table 6 the botanical composition of the clippings is given. The effect of nitrogen in increasing the percentage of grasses is evident, although the percentage of clover remained comparatively high when nitrogen was added to complete mineral treatments. Combinations containing limestone and (or) potassium gave the highest percentage of clover. In some cases, particularly with the heavier applications, the addition of phosphorus further increased the percentage of clover.

Table 6.—Botanical Composition of Clippings from the Amherst Pasture Experiment, 1931

(Expressed as per cent)

Treatment	First Cutting				Second Cutting			
	No Nitrogen		Nitrogen		No Nitrogen		Nitrogen	
	Grass	Clover	Grass	Clover	Grass	Clover	Grass	Clover
K	37	0	75	0	50	1	75	4
P	36	5	82	1	73	3	81	1
L	43	40	68	13	50	39	71	15
L, P	65	21	90	6	79	16	74	23
P, K	51	9	85	8	34	22	81	12
L, K	36	56	69	26	40	51	51	44
L, P, K	38	52	51	41	59	34	64	33
2K	65	1	89	1	57	6	31	4
2P	53	17	89	1	71	2	92	2
2L	76	11	89	4	65	13	79	13
2L, 2P	51	31	79	7	51	35	65	30
2P, 2K	58	32	77	19	67	27	66	31
2L, 2K	64	25	89	6	55	34	74	19
2L, 2P, 2K	60	33	65	28	56	37	64	31
3K	92	0	88	4	96	0	83	13
3P	94	0	99	0	88	0	98	0
3L	72	14	92	0	65	29	88	0
3L, 3P	68	23	81	7	96	1	91	4
3P, 3K	98	0	98	0	56	42	98	0
3L, 3K	72	23	89	2	73	26	80	16
3L, 3P, 3K	16	52	71	25	66	12	74	25
Check	33	0	77	0	53	1	76	0

The toxic effect of sodium nitrate for haircap moss (*Polytrichum commune* L.) was first noted in Amherst experiment C and was reported in previous publications (1). Further evidence in support of this observation was obtained from the experiments in Worcester County. The toxic effect was definite, and the action cumulative from year to year, so that in the course of four years bad infestations of this moss were almost or entirely eliminated by moderate applications of sodium nitrate.

Further, an interesting observation was made in both the Amherst and Worcester experiments regarding another moss, a small yellowish green species known as *Funaria hygrometrica* (L.) Sibth. It was observed that this species grew in spots not covered with other vegetation, on plots which had received moderate applications of ground limestone or heavy applications of superphosphate. It appears, therefore, to be indicative of available calcium. Since this moss is very small it is not expected that it can successfully compete with higher forms of plant life, and its presence has no practical bearing except as an indicator of available calcium.

The Question of Phosphate for Pastures

The work on fertilizers for upland pastures, either at Amherst or in Worcester County, has not indicated as strong a response to phosphorus as has been reported from some other states. More response has been indicated from the Amherst experiments than from those of Worcester County. For both these sections, the case for lime, nitrogen, and potash appears to be fairly well established, at least for the type of soil and duration studied. Field work of this nature is subject to a considerable experimental error and, therefore, the tests should be continued and amplified before final conclusions are drawn. Other soil types should be studied.

The question of the importance of phosphorus for our upland pastures is one about which considerable discussion revolves. Therefore, special attention was given this question in this study. As shown in Table 4 a marked difference in response to phosphorus was obtained in the results from certain fields in Worcester County. An attempt was made to correlate the difference in response with certain physical and chemical characteristics listed in Tables 1, 2, and 7. It was suspected, for example, that phosphorus response might be best on soils of high sand and low colloidal content because of the low absorptive capacity of such soils. This appears to hold for experiments W-1 and W-9 but breaks down in a measure for the other fields. There is even less correlation between phosphorus response and loss on ignition or organic matter.

TABLE 7.—PHOSPHORUS RELATIONS OF PASTURE SOILS

(Calculated on air-dry basis)

Experiment	Pounds per Acre Readily Available Phosphorus*	Pounds per Acre Difficultly Available Phosphorus**	Fixing Capacity Per Cent***
W-1	Trace	370	65
W-2	40	1520	74
W-5	32	860	55
W-9	13	520	55
H-15	31	840	75

*Using Truog's method.
**Soluble in N/5 H_2SO_4.
***By a method of A. F. Heck, University of Wisconsin.

An attempt was then made to correlate phosphorus response with extractable phosphates and fixing capacity of the soil for phosphates. These data are given in Table 7. Phosphates assumed to be readily available to plants were determined by a method recommended by Truog (6). In this method a buffered solution of

0.002 N H_2SO_4 is used as the solvent. According to Truog sandy soils should yield a minimum of 50 pounds per acre of readily available phosphorus for general farming. By this criterion all these soils are below the minimum limit for phosphorus and should respond strongly to applications of phosphates, but with the exception of W-9, no marked response to this element was obtained in these experiments. However, W-1 soil contained only a trace of readily available phosphorus, and gave a negative response to phosphates. But in this case, as also it may be with W-2, the soils showed a comparatively high fixing capacity for phosphates. Apparently the chemical fixing capacity of soils for phosphates is fully as important as the amount of readily available phosphorus in determining their response to phosphatic fertilizers. It is interesting to note, and is probably significant from a diagnostic standpoint, that of the four Worcester soils studied in detail the two that showed a positive response to phosphorus also showed the lowest fixing power.

Phosphates soluble in N/5 H_2SO_4 were also determined by a modification of the method used for the readily available phosphates, and are indicated in Table 7 as pounds of difficultly available phosphorus per acre. This represents the native phosphorus that may be expected to become available through a long period by the natural weathering agencies. These figures, together with such chemical analyses as have been made indicate that the soils of Massachusetts are well supplied with native phosphates. In 194 miscellaneous samples (3) from different parts of the state the average content of P_2O_5 soluble in strong acid was 0.214 per cent; of 17 samples from Worcester County 0.25 per cent, or about 2200 pounds of phosphorus per acre of soil to plow depth. The total phosphorus will exceed this figure by about 25 per cent. But this large quantity of native phosphorus is, like the immense store of native potassium in our pasture soils, for the most part only slightly available to plants.

Midgeley (4) and Weiser (7) studied certain factors affecting the penetration of phosphates into soils. They showed that the phosphoric acid of superphosphate penetrated soils more slowly than did that of certain other carriers, notably sodium phosphate. These writers (5) called attention to "positional" and "chemical" fixation of phosphoric acid by soils. Positionally fixed phosphoric acid is in a readily available form, but largely unavailable to plants because it remains in the surface layers of the soil and, therefore, out of reach of most of the roots. Chemically fixed phosphoric acid is unavailable to plants by reason of its having entered into difficultly soluble chemical combinations. That both positional and chemical fixation of phosphates seem to have been high in Amherst pasture soil is indicated by the figures of Table 8. For example, on plot 2P 243.3 pounds per acre of phosphorus were applied in the course of 8 years, but only 108 pounds were found in a readily available form in the first 4 inches. With a reasonable allowance for available phosphorus originally in the soil and that removed by the crop, it appears that about 31 per cent of the applied phosphorus was positionally fixed, and 69 per cent chemically fixed. This latter figure compares favorably with the 75 per cent of chemical fixation given for soil H-15 in Table 7.

It may be noted, however, that even with the comparatively large amounts of available phosphorus from the 2P and 3P treatments, the growth of vegetation was low, averaging only 403 and 329 pounds for these treatments respectively, for the years 1931 and 1932; but when nitrogen was added to the phosphorus treatment the yields were more than doubled. It appears that even if sufficient available phosphorus is present in our upland pasture soils, deficiencies of other

nutrients, especially nitrogen, may limit growth. This statement applies particularly to vegetation composed mainly of grasses. As shown by the data, in good "clover years" white clover may grow luxuriantly on plots receiving only minerals (L, P, K); but, as shown in an earlier bulletin (1) "clover years" are irregular and uncertain in occurrence, and not understood as to cause.

The effect of lime in increasing the ready availability of applied phosphorus is shown by the data of Table 8. This is especially well shown by the 2P and 3P treatments in comparison with the same treatments plus lime. No doubt, one of the principal benefits of lime in pasture improvement is this effect on availability of phosphorus.

TABLE 8.—EFFECT OF PHOSPHATE AND LIME APPLICATIONS ON AMOUNT OF READILY AVAILABLE PHOSPHORUS IN THE AMHERST PASTURE SOIL*

Treatment	Pounds Available P per Acre Air-dry Soil	
	First 4″	Second 4″
P	56	36
P, L	42	42
2P	108	56
2P, 2L	166	110
3P	232	78
3P, 3L	392	208

*Method of Truog.

The recent publication of Brown (2) shows that fertilizer nitrogen (nitrate of soda and other carriers used) and lime, independently of each other increased the effectiveness of phosphorus; nitrogen more than lime. Midgeley (4) showed that sodium nitrate greatly increased the penetrability of phosphorus in soils. A determination of readily available phosphorus in soils which received no nitrate and the corresponding treatment with nitrate, Amherst experiment, showed slightly more available phosphorus in the nitrated plots. More phosphorus was removed from the nitrated plot in its larger crop. There is therefore, some evidence from this experiment that sodium nitrate is of considerable indirect value because of its effect on the availability of the phosphorus.

Summary

Results of top-dressing with chemical fertilizers experimental fields on two soil types are reported in this bulletin. The principal results are as follows:

1. In the Worcester experiments, with the exception of phosphorus, the effects of the different added nutrients were mainly cumulative.

2. The net mean increase due to phosphorus was 20 pounds dry material; to potassium 343 pounds; to nitrogen 556 pounds; and to calcium (as limestone) 230 pounds per acre.

3. In the Amherst experiments nitrogen was more effective than any other single element, but was not so effective as the best combination of mineral elements. Nitrogen and minerals were mutually helpful in increasing yields.

4. Certain combinations of minerals, especially those containing limestone and (or) potassium, were effective in increasing the proportion of white clover in the vegetation. In some cases, particularly with heavy applications, the addition of phosphorus further increased the proportion of clover.

5. The previously noted toxic effect of nitrate of soda for haircap moss (*Polytrichum commune* L.) was corroborated by the Worcester experiments, and it was observed that a small, yellowish green moss (*Funaria hygrometrica* (L.) Sibth.) grew especially well on bare spots of limed soils or heavily phosphated soils.

6. An attempt was made to correlate phosphorus response with certain physical and chemical characteristics of soils. Readily available phosphorus and the fixing capacity of the soil for phosphorus were factors. Little direct relation was noted between phosphorus response and colloidal content, organic matter, and loss on ignition.

7. It was shown by chemical analysis that large amounts of applied phosphates were both "positionally" and "chemically" fixed in the pasture soils studied.

8. It was shown that many Massachusetts soils contain comparatively large potential supplies of native phosphorus, but in a form only slightly available.

9. Further, it was shown that even if from heavy fertilization large amounts of readily available phosphorus were present in the soil, other nutrient deficiencies may limit the growth of pasture plants.

10. Lime increased the amount of readily available phosphorus in soils treated with phosphates. There was some evidence that nitrate of soda, also, increased the availability of applied phosphates.

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Publication of this Document Approved by Commission on Administration and Finance
4M-2-'34. No. 484.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 307 APRIL, 1934

Breeding for Egg Production

By F. A. Hays and Ruby Sanborn

During the last twenty years the Poultry Husbandry Department has conducted numerous investigations to determine the influence of various factors, controllable through breeding, on the egg-producing ability of Rhode Island Reds. This compilation of results obtained up to the present date is intended as a guide to assist the poultry breeder in directing his operations.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

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BREEDING FOR EGG PRODUCTION

By F. A. Hays, Research Professor, and Ruby Sanborn, Research Assistant, in Poultry Husbandry

In a study of the mode of inheritance of high fecundity, Rhode Island Reds have been bred experimentally at the Massachusetts Agricultural Experiment Station for a period of twenty-one years. The data presented in this report cover the birds hatched from 1913 to 1932, inclusive, and are based very largely on pullet-year records.

A number of significant discoveries related to the inheritance of fecundity have been made from time to time as this experiment progressed and these have already been reported. This report summarizes the methods of breeding and the results accomplished up to the present time and may serve in a measure as a guide to poultry breeders.

The General History of the Flock[1]

The initial flock consisted of 144 single-comb Rhode Island Red pullets purchased in the fall of 1912. The major portion of the birds came from one prominent exhibition flock and the remainder from another well-known exhibition flock. These pullets were housed in two units and trapnested throughout the year. The original records include date of first egg, hour of laying, broody records, nesting records, and sickness or injury notes, together with egg records to March 1 and for 365 days from first pullet egg.

The males used to produce the first generation in 1913 came, with one exception, from the same breeding farm as the major portion of the original females. The generation produced in 1914 was sired largely by the original males or their sons, but in addition four outside males from different sources were used for breeding. The results obtained with the generations hatched in 1913 and 1914 were not considered satisfactory because the birds were lacking in vigor. For this reason, ten outside males from widely different sources were used for breeding in 1915, besides a few of the foundation males and a number of their sons. Since the breeding season of 1915, outside stock has not been used in this experiment. Since 1920 all males used as breeders have been found to trace back exclusively either to one original male used in 1913 or to one outside male introduced in 1915.

The first generation of offspring was hatched in 1913 between March 25 and May 15, at weekly intervals. The same hatching dates with eight weekly hatches have been maintained through 1932. The method of feeding and management has been changed only gradually to conform to modern developments.

Artificial methods such as confinement rearing have never been employed, the chicks when taken from the incubators being placed in 6 × 6 colony brooder houses heated by kerosene brooders up to 1917; after 1917 in 10 × 12 colony brooder houses heated by stoves. Up to 1921 pullets were regularly housed when about six months of age in units of about 100. Beginning in 1922, pullets

[1]The experimental work reported here was planned and directed by H. D. Goodale from 1912 to 1922. Since 1922 the work has been carried on by F. A. Hays.

were housed in units of 250 at the new experimental poultry farm. Artificial lights have never been used.

Modern methods for disease control, such as range rotation, complete separation of growing and adult stock, and cleaning and disinfecting of houses and equipment, have been regularly employed. For many years all birds have been tested yearly for pullorum disease, and in recent years chicken-pox vaccination has been practiced regularly either at housing time or on the range at about twelve weeks of age. Up to the fall of 1926 all birds in the laying houses were self-fed laying mash in hoppers and grain twice daily in the litter. On November 19, 1926, self-feeding whole corn, oats, and laying mash was begun.

The Qualities of an Improved Flock

In general, an improved flock should consist of birds very uniform for all the known desirable characters from the standpoint of fecundity; the birds should be free from standard defects; there should be very high hatchability, low mortality, and a high degree of prepotency.

An ideal hen should possess the following qualities: Standard weight; early sexual maturity; high intensity; no winter pause; non-broodiness; high persistency; large egg size; first quality color, shape and shell texture of eggs; high hatchability; strong vigor; trueness to breed standard; and prepotency. When these requirements are considered individually in view of what is known regarding their inheritance, the fact becomes very evident that the development of an improved flock possessing all the desirable qualities is a gigantic undertaking requiring large numbers of birds, careful observation, complete records, and a knowledge of genetic principles involved. The measure of success in poultry breeding is the degree of uniformity in the flock with respect to all the characters bred for.

The Plan of Breeding

The description of the plan of breeding may logically begin with the method of selecting breeders. Since the male contributes to the inheritance of a greater number of offspring than does the female, his selection may be considered first.

Males have been selected in part each year by three different standards. Aged males that were physically fit and that had sired a superior group of daughters were used, and satisfactory matings were repeated as far as possible. Cockerel breeders were selected each year both on their pedigree and on the performance of their sisters with respect to characters affecting fecundity up to the breeding season. Each male was selected on physical characters as far as available birds permitted. In the earlier years not much attention was paid to plumage color or to physical defects in comb, shank, feathering, split wings, etc. During the past five years great care has been exercised not to breed from either males or females with physical defects, and some attention has been given to improving plumage color.

All hen breeders were selected on their fecundity characters and on the performance of their daughters. Pullet breeders were chosen on pedigree and on their performance up to the breeding season. Heavy body weight has always

been emphasized. Each year a surplus of pullet breeders has been placed in the mating pens in order that the offspring from such as proved unsatisfactory in hatchability, in egg character, in broodiness, or in lack of persistency might be discarded.

After the discovery that five specific characteristics were associated with high fecundity, the method of breeding was directed toward the establishment of these in the entire flock. The characters bred for were early sexual maturity, high intensity, no winter pause, non-broodiness, and high persistency. The early efforts were directed toward establishing early sexual maturity by the selection of female breeders that began to lay at an early age, and this standard has been rigidly adhered to. Efforts were next made to reduce broodiness through the use of non-broody females or females with a low degree of broodiness for breeding. High intensity was the third character sought for, and was established in the flock by one hen, B785, hatched in 1917 and used first for breeding in 1918 and again in 1919 and 1920. Seven of the daughters of this hen and one son were also used. Efforts to eliminate winter pause entirely followed the establishment of high intensity. Breeding females were selected as far as possible that showed no cessation of production between November 1 and March 1. The last character to be established was high persistency. Selection of breeders for this purpose was based on ability to lay late in the fall before undergoing annual molt.

Throughout the experiment attention has been given to high hatchability, and during the past five years special attention has been given to egg size and egg character and to mortality rate as well as to the elimination of physical defects and to the improvement of plumage color.

All matings made since 1913 have been pedigree matings, and a complete hatching record has been kept of all eggs set. Infertile eggs were removed on the fifth day. All eggs carrying dead germs were removed on the fifth day or on the eighteenth day, broken, and the embryos checked. Eggs were placed in pedigree baskets on the eighteenth day and the chicks taken out on the twenty-second day. All remaining unhatched eggs were then broken and the embryos examined. Chicks were banded from the incubator using No. 3 pigeon bands placed around the leg and transferred to the wing at two weeks of age to serve as the permanent number of the bird. Sexes were separated at about eight weeks of age, and pullets placed in the laying houses according to hatching date at about 150 days of age. Complete pullet families were housed, except crippled or diseased birds.

The Changes in the Average Character of the Flock

Progress in breeding for particular characters can best be measured by averages from year to year, provided the number of birds concerned is sufficiently large to be respresentative. In Table 1 are presented the averages for a considerable number of characters throughout the experiment. The table includes only birds bred for high fecundity in the flocks hatched from 1916 to 1932. Annual records are not available on the flock hatched in 1919 because the birds were disposed of after the hatching season on account of disease and parasites.

The table shows that early sexual maturity was rather well established in the 1917 flock, and that the fluctuation in mean age at first egg has ranged from 185 to 212 days in a 16-year period. The fact should be stated that the mean age at first egg of the 1913 flock was 255.61 days.

TABLE 1.--YEARLY AVERAGES SHOWING PROGRESS IN BREEDING FOR PARTICULAR CHARACTERS.

(Includes all pullets or breeders each year in the flock bred for high production. The number of birds in the different columns varies somewhat.)

Year Hatched	Number of Birds Put in Laying House	Age at First Egg Days	Weight at First Egg Pounds	Birds with Winter Pause Per cent	Winter Clutch Size Eggs	Broody Birds Per Cent	Broody Periods per Broody Hen		Persistency Days	Annual Production Eggs	Laying House Mortality Per cent	Hatchability	
							Number	Length-Days				Per cent	No. of Birds
1916	330	229.71	6.07	56.99	2.5	86.31	3.5	14.29	247.53	133.67	9.37	65	(62)
1917	432	212.96	5.68	60.97	2.3	48.84	2.7	16.36	280.74	165.85	15.05	62	(78)
1918	474	194.41	5.75	67.34	2.3	61.40	2.9	15.06	287.98	169.19	56.54	65	(89)
1919	157	212.01	5.42	64.97	2.8	.....	...	.....	.....	.....	.....	69	(56)
1920	162	199.99	5.48	74.67	2.7	46.03	2.9	12.85	330.86	199.73	26.09	70	(45)
1921	410	211.51	5.27	35.05	3.3	41.56	2.7	15.03	303.94	198.40	29.09	73	(67)
1922	565	196.60	5.39	64.06	2.7	28.91	1.9	14.17	321.92	199.55	31.68	71	(83)
1923	472	208.77	5.57	76.98	2.4	27.35	1.9	15.57	323.54	189.09	26.06	73	(62)
1924	422	196.26	5.53	65.80	2.5	32.90	2.3	15.10	326.57	196.41	50.00	54	(142)
1925	553	192.05	5.39	80.77	3.1	41.55	2.7	14.81	330.24	205.21	22.97	63	(130)
1926	479	198.56	5.35	70.00	2.7	19.31	2.3	15.03	331.36	205.26	32.57	64	(124)
1927	551	185.30	5.40	70.73	3.5	9.55	1.2	18.19	320.67	197.38	23.23	57	(150)
1928	560	195.82	5.33	58.33	3.4	18.44	2.5	13.67	335.20	214.82	14.29	60	(174)
1929	507	197.08	5.50	61.93	3.1	12.69	1.8	13.74	329.87	208.40	33.73	75	(108)
1930	461	191.24	5.41	50.49	3.7	22.52	2.3	14.51	339.60	214.34	29.28	74	(79)
1931	462	188.77	5.58	39.54	3.8	16.52	2.1	14.23	344.40	234.23	17.10	70	(90)
1932	377	201.69	5.88	57.05	3.3	11.70	2.1	12.90	337.79	222.14	35.54	66	(83)

Each pullet was weighed on the day she laid her first egg. The table shows that this mean weight has not fluctuated widely throughout the experiment and that the birds hatched in 1932 were slightly heavier than any other flock except the 1916 flock. This latter flock owes its greater weight to a greater age as Hays (1933a) has pointed out. The data in general indicate that breeding for high fecundity has no significant effect on body weight at first egg.

The nature of winter pause is fully discussed in a later section of this report. The table shows that the percentage of birds showing a winter pause of four or more days has fluctuated from a minimum of 35.05 in 1921 to a maximum of 80.77 in 1925. During the last five years there is some progress apparent in eliminating the trait, but on the whole this character has not responded well to breeding methods used.

Intensity, measured by winter clutch size, shows a highly significant improvement. This is especially noticeable during the last six years, during which winter clutch size has been used as the sole measure of intensity in the selection of breeders. The mean clutch size in recent years shows that the majority of the birds carry both genes I and I′ for large clutch size.

Broodiness is measured by the percentage of birds broody the first year, by the mean number of broody periods for broody individuals, and by the mean length of broody periods. The data show clearly that broodiness may be greatly reduced by selection of non-broody breeding stock. In the flock of 1916 slightly over 86 per cent of the females became broody in the first laying year, while in the 1932 flock 11.7 per cent exhibited the trait. Quantitatively broodiness as measured by the number of broody periods per broody individual has decreased from an initial mean of 3.5 periods to a mean of 2.1 periods. The mean length of broody periods, measured by the non-productive time interval, remained unchanged throughout the experimental period and ranged very close to 15 days.

Annual persistency within a 365-day laying year has increased significantly during the experimental period. The mean initial persistency was about 248 days, and the mean persistency at the close of the experiment about 340 days. The most notable progress since 1920 has been made during the last five years. This increase is due in large measure to the more rigid selection of breeders for greater duration of laying and to the use of more aged breeders with greater length of biological laying year. This latter basis of selection is very effective according to Hays and Sanborn (1933).

Mean annual egg production stood at about 134 eggs in 1916. It increased rather rapidly to 200 eggs in 1920. The production then remained at the 200-egg level for five years. Beginning with 1925, the trend has been upward to the highest mean of 234 in 1931. Production has not advanced a little each year but has increased by rather abrupt advances at intervals accompanying the establishment of a desirable character in a large percentage of the flock. Attention is called to the fact that these egg records represent the mean of all normal birds in each family that lived to complete a 365-day record, and that no culling was done during the laying year.

Mortality in the laying houses has varied widely throughout the period reported. The records do not show that mortality has increased as the breeding work progressed and as the egg production level was raised. Records during the

last eight years, in the absence of specific disease outbreaks, have fallen as low as 15 per cent in only one year. Experience and observation indicate that a laying-house mortality above 15 per cent is excessive. It is probable that selection of breeders for low family mortality has not been rigid enough because of efforts to establish other desirable characters. Another possibility is that, since no outside stock has been introduced since 1915, the flock may be restricted to too close relationships even though inbreeding has been avoided. There is no experimental proof to support this possibility, however.

The last double column gives the mean percentage of fertile eggs hatched, together with the number of females used (in parentheses). Hatchability has improved very slightly during the whole period. It seems probable that more attention should be given to this character in the selection of breeders.

The Relation Between Fecundity Characters and Egg Production

Goodale and Sanborn (1922) pointed out that there are five prominent characteristics that tend to increase the annual egg production of Rhode Island Reds. These characters are early sexual maturity, high intensity, no winter pause, non-broodiness, and high persistency. Hays (1924 and 1927) showed that these characters are inherited and that a total of eight genes is concerned. If the five characters are considered as units, there are thirty-one types of birds each representing a different combination of the five. There are five types of individuals each carrying one of the five desirable characters; ten types, each carrying two desirable characters; also ten types, each carrying three desirable characters; five types, each carrying four desirable characters; and one type having all five desirable characters combined. A rough measure of the degree of improvement in the flock for egg production would be the percentage of birds combining either four or five of these desirable characters. Table 2 shows that the average egg record of birds increases as the number of desirable characters increases. The table includes 2300 birds hatched from 1928 to 1932.

Table 2.--Relation of Number of Desirable Characters to Annual Production.

Number of Characters	Number of birds	Per cent of Birds	Average egg Production
0	31	1.35	149.03
1	158	6.87	156.73
2	375	16.30	173.78
3	717	31.17	200.83
4	648	28.17	227.32
5	371	16.13	252.15

Table 2 shows that the 31 birds classed as having neither early maturity, high intensity, no winter pause, non-broodiness, nor high persistency averaged 149 eggs, showing that they must have been maintained under good laying conditions. No doubt a number of these individuals are improperly classified because of the variability in each character that always occurs. The table shows further that the group of 158 birds carrying only one of the five characters averaged to lay about 157 eggs. From this class on, the addition of any one character increased

the mean production about 25 eggs, so that the group having all five desirable characters averaged to lay 252 eggs a year.

The rate of progress in establishing these characters in the flock during the last five years is rather definitely indicated by the percentage of birds in the different groups. The classes showing three and four of the desirable characters make up 59.34 per cent of the entire population. The classes having two of the characters and those having all of the characters are equally represented with about 16 per cent. Theoretically the flock is improved only to the extent of about one-sixth of what may be anticipated, for there is no known reason why 100 per cent of the birds cannot carry all five desirable characters. There are at present 65,496 genetically different classes of birds in the flock with respect to the five characters considered. This fact shows why progress is slow in establishing characters in a small flock, and it is very evident that little progress can be made in flocks consisting of fewer than 500 individuals.

Early Sexual Maturity

Unpublished data show that the regression of annual egg production on age at first egg is not strictly linear and that the correlation ratio shows a value of $.6056 \pm .0112$. Hays and Sanborn (1927b) have shown, however, that the net correlation between age at first egg and annual egg production is insignificant and that early-maturing birds generally lay more eggs only because they tend to be more intense layers and are generally more persistent.

Even though early sexual maturity in itself is not essential to high annual production, its association with other essential characters gives it a high value as a selection unit in production breeding. This character was the first to be selected for in this experiment, was reasonably well established first in the flock hatched in 1917, and has behaved with a high degree of constancy up to the present time.

Early maturity behaves in inheritance as a dominant to late maturity as Hays (1924) showed. Two independent dominant genes,[2] E and E′, are concerned, either of which will enable pullets to begin laying at 215 days or less. Gene E is sex-linked and is transmitted by males to both sons and daughters and by females to their sons alone. Gene E′ is autosomal and is transmitted equally by both parents. No cumulative effect has been discovered for these genes.

High Intensity

High winter intensity (large clutch size) is an inherited character that has a very significant effect on annual egg production. Winter clutch size was shown by Hays and Sanborn (1927a) to be significantly correlated with production, giving a value of $+.3544 \pm .0117$. The same workers (1932) showed that the regression of annual production on winter clutch size is non-linear, giving a correlation ratio of .4214. Hays and Sanborn (1927b) found the net correlation between winter clutch size and annual egg production to be $+.4944 \pm .0101$ which shows clearly that high intensity is essential to maximum egg production.

[2]In genetic terminology capital letters stand for dominant genes and small letters for recessive genes. Individuals are said to be homozygous for a gene when they carry two doses as HH or hh and heterozygous when they carry two different genes as Hh. The first class of individuals breeds true for the character in question—they are prepotent. The second class gives two types of offspring, one carrying H and one carrying h, in equal proportions. The same general principles apply to other genes discussed in this report.

The mode of inheritance of intensity has been reported by Hays and Sanborn (1927b). Two dominant genes I and I′ are concerned. Hens carrying gene I alone have an average winter clutch size greater than 2 but less than 2.6. Gene I′ gives a clutch size of about 2.6. Both genes together increase the clutch size up to 3 or more eggs throughout the winter season. There is no sex linkage for clutch size. Improvement in clutch size has been made possible through the use of breeding stock showing the ability to lay large numbers of eggs in succession throughout the winter season. The minimum winter clutch size for breeders should be 3 eggs, and males should be constantly selected for the ability to transmit large clutch size to their daughters.

Winter Pause

Winter pause or the cessation of laying for four or more days between November 1 and March 1 of the pullet year reduces the number of eggs laid in a year. The simple correlation between length of pause and annual production is reported by Hays and Sanborn (1926b) to be $-.2107 \pm .0176$, and the net correlation was given as $-.5487 \pm .0128$ (Hays and Sanborn, 1927b). The fact is very evident, therefore, that the appearance and duration of the pause exercises a very significant influence on the number of eggs laid.

The data from this station point rather definitely to both inheritance and environment as responsible for winter pause. There is very great difficulty in separating the two causes, and this retards progress in eliminating pause from the flock. The fact that, in full sisters hatched on the same date and housed together, some exhibit pause and some lack it, rather strongly suggests that inheritance is concerned. Furthermore, the average duration of pause per family has been reduced by selection even though the proportion of birds without the four-day pause has not significantly changed during the last twenty years. There appears to be one dominant factor M concerned in hereditary pause, as Hays (1924) points out. The logical procedure in eliminating this character consists in the constant selection of pause-free breeders and in hatching and housing under optimum conditions at all times.

Broodiness

Broody periods represent periods when production ceases. On the average, each broody period occasions a loss of about fifteen days of egg production. Hays and Sanborn (1926a) reported that, of the original flock hatched in 1912, 89.6 per cent were broody during the first laying year. As the experiment has progressed the percentage of broody birds has greatly decreased, reaching a minimum of 11.7 per cent in 1932. Along with the decrease in percentage of broody birds there has occurred a high reduction in number of broody periods per broody individual. For example, the 1913 flock averaged 5.4 periods per individual broody bird, while the 1923 flock averaged but 1.9 periods per broody bird. Hays (1933b) presents definite experimental evidence showing that degree of broodiness measured by number of broody periods depends on inheritance.

The presence of broodiness has been shown by a number of workers to greatly reduce egg production. Jull (1932) reports that 494 non-broody Rhode Island Red birds averaged 204.78 eggs, compared with 179.65 eggs for 477 broody birds. Hays (1933b) reported that 267 birds in a non-broody line averaged 209.81 eggs, while 259 birds in a broody line averaged 179.02 eggs. The net

correlation between days broody and egg production in the pullet year is —.5630 ±.0097 in the station flock.

Broodiness is inherited on a two-factor basis according to Goodale, Sanborn and White (1920). Two dominant complementary genes, A and C, are necessary to produce broodiness. There is no evidence of sex linkage, and non-broody birds are of three general classes: (1) those lacking both A and C; (2) those carrying A and lacking C; (3) those carrying C and lacking A. Classes 2 and 3 are very troublesome to the breeder because such females, though not exhibiting broodiness, will produce broody offspring if mated with males carrying the gene that they lack. This is one of the chief reasons why broodiness has never been completely eliminated from any flock. Another obstacle in eliminating broodiness lies in the problem of deferred broodiness. In such cases the instinct may not appear in many females during the first or second laying years. This fact renders an accurate progeny test of males almost impossible with the American breeds.

A constructive breeding program calls for the constant use of non-broody hens for breeding and the use of progeny-tested males to the greatest extent possible.

Persistency

Persistency at the close of the pullet laying year has been shown by Hays and Sanborn (1927b) to be the most important inherited character affecting annual egg production. The net correlation between length of laying year and annual production is +.7501 ±.0063. This fact indicates that more than 56 per cent of the variation in annual egg records is due to differences in persistency. Hays and Sanborn (1933) have pointed out further that persistency higher than 365 days is desirable in breeders from the standpoint both of increasing egg production and of reducing mortality in daughters.

Hays (1927) has presented some evidence concerning the mode of inheritance of high persistency. His data indicate that high persistency depends upon one dominant autosomal gene, P. According to this report the dividing point between birds genetically high and low in persistency lies at about 315 days from the first pullet egg. In breeding for persistency, no females laying for a shorter period than 315 days should be used for mating, and male breeders should carry an equally good or superior inheritance for persistency.

The Hatchability Problem

Extensive experimental observations by many investigators indicate a wide range in percentage of fertile eggs hatched by different birds. Experience also furnishes evidence that constant selection for high hatchability is necessary in improved flocks in order that hatchability may not decline. Experimental workers are agreed that hatchability is an individual trait depending upon both inheritance and environment.

Egg size does not affect hatchability as Jull (1932) shows from his own studies as well as from the work of other investigators. The physical characters of eggs such as shape and shell texture do not influence hatchability if the eggs are normal. On the basis of these facts, the selection of hatching eggs for size and physical characters does not seem to have any significant effect on hatchability.

Age of birds used does not consistently affect hatchability. Hays (1928) presents some evidence that for identical matings there is a slight increase in hatchability of yearlings compared with pullets. When different groups of pullets, yearlings, and old hens are compared for mean hatchability, the station records from 1924 to 1931 show the following means: 65 per cent for pullets, 75 per cent for yearlings and 65 per cent for old hens. In the experiment station flock there is, therefore, some evidence indicating that females are likely to hatch the highest percentage of fertile eggs during their second laying year.

The most potent factors affecting hatchability are inherited factors, according to the work of Hays and Sanborn (1924). They have clearly demonstrated that the hatching record of a hen depends largely upon her inheritance and upon the character of the male to which she is mated. In other words, the embryo's inheritance from its sire and dam either equips or fails to equip it to emerge normally from the shell.

Studies at the Massachusetts Station indicate that one major gene, H, is concerned in high hatchability. This gene is transmitted equally by males and females and has a cumulative effect. The three general classes of birds with respect to hatchability are: (1) HH birds which, if mated to either HH or Hh males, give hatching records of 85 per cent or more; (2) Hh birds which usually have a hatchability range from 55 to 84 per cent and may produce no hatchable eggs; and (3) hh birds which generally range in hatchability from 0 to 54 per cent. Females that have shown a hatchability of 85 per cent or more are HH in genetic make-up, and breeding birds should always be selected on this basis. Males should be chosen on the hatching record of their female ancestors and insofar as possible upon the actual hatching records of their daughters.

By giving some attention to hatchability in the station flock, the mean has been raised from about 58 per cent in 1914 to a maximum of about 82 per cent in 1933. A portion of this increase may be attributed to improved incubation facilities, but in general there has been an upward trend under the same system of incubation. Attention should be called to the fact that all eggs have been pedigree hatched which necessitates considerable extra handling and exposure to temperature changes and has been shown to lower the hatching records from 10 to 15 per cent over ordinary incubation in this flock.

The Vigor Problem

High vigor in a production-bred flock may be defined as the ability to live and produce heavily for a long period of time under intensive conditions. Records of the mortality rate in families on the growing range and in pullets in the laying houses show striking differences between families. It is a reasonable assumption that the great proportion of these losses come from lack of vigor, because diagnostic records show the flock to be relatively free from specific disease outbreaks. The flock has been free from pullorum disease for many years, and pox and roup have been controlled by vaccination. Coccidiosis has been held in check by a four-year range rotation and by quarantining against visitors or caretakers of adult fowls.

From October 1, 1932 to September 30, 1933, complete post-mortem records were made by the Department of Veterinary Science on all pullets of the experimental flock hatched in 1932. The records begin at the time the birds were

housed and continue for one year. The causes of mortality have been grouped into fourteen general classes, and the original number of pullets housed was 751.

	Per cent
Ruptured or obstructed oviduct	2.53
Ruptured egg yolks, peritonitis	1.33
Tumors	2.93
Worms	1.86
Leukemia	3.20
Visceral gout, nephritis	2.26
Impaction	1.20
Paralysis	2.66
Chronic coccidiosis	.27
Prolapsus	.93
Cannibalism	6.79
Injury	.67
Miscellaneous	4.13
No recognized cause	9.99
Total loss	40.75

Examination of these records does not point to any specific diseases as predominant causes. The greatest percentage of birds died from miscellaneous causes not common in the flock. Almost 10 per cent of birds showed no specific cause on post mortem. Leukemia, tumors, paralysis and ruptured or obstructed oviduct appear as most potent specific disorders in the flock. The loss of 6.79 per cent from cannibalism cannot be due to lack of vigor but is probably due entirely to faulty management.

From the standpoint of breeding to reduce mortality, the logical procedure is to select breeders from families with the lowest mortality. Neither breeding males nor breeding females should be used from families with a greater mortality than 10 per cent between hatching and housing in the fall. The yearly mortality in pullet families in the laying houses should not exceed 15 per cent including those culled. The mortality from housing time in the fall up to the breeding season in February or March should not be greater than 5 per cent.

The Influence of Inbreeding

Inbreeding is a useful tool of the breeder in securing uniformity because the mating of closely related individuals tends to increase homozygosity. This method of breeding has been extensively used in developing new breeds and varieties where the chief concern is uniformity in type and plumage character and color.

Inbreeding in production-bred flocks has not given encouraging results according to the work of a number of investigators. Dunn, Hays, Dunkerly and Jull have all reported that inbreeding decreases egg production. Extensive studies by Hays (1929b) show the following undesirable results from inbreeding Rhode Island Reds: sexual maturity was retarded, winter pause increased, intensity lowered, persistency lowered, egg production decreased, fertility lowered, hatch-

ability decreased, and vigor reduced. No significant gain in uniformity of annual egg production was observed under inbreeding. The deduction is made from these studies that only flocks made up of very diverse foundation stocks will tolerate inbreeding. As a rule, for ordinary improved flocks, much greater progress will be made by selection on the basis of individual fecundity characters and the avoidance of matings closer than cousins in the flock.

Breeding For Egg Size

Egg size depends indirectly upon a great many inherited characters. Some of these characters are age at first egg, body weight at first egg, and intensity of laying. Hays (1930a) showed the correlation between age at first egg and mean egg weight to January 1 to be $+.4280 \pm .0148$ in Rhode Island Reds. The correlation between body weight at first egg and egg weight to January 1 was $+.4314 \pm .0147$. Hays (1930b) presented evidence that egg size is not linked with either factor for early sexual maturity and this fact suggests that the reason why there is a significant correlation between age at first egg and winter egg size is due to the direct relation between age and weight at first egg. Hays (1930b) demonstrated a specific linkage between gene A for small egg size and gene I′ for highest intensity. In view of these findings, it is evident that poultrymen should take great care in selecting breeders for high intensity that they do not carry the gene for small egg size.

Parkhurst (1933) reviews the effect of nutrition on egg size and shows that in general either inadequate food supply or lack of proper protein in the ration may reduce egg size. Parkhurst's data indicate that birds fed rations deficient in vitamin D lay small eggs, that the addition of milk to the ration increases egg size, but that minerals added to the ration do not affect egg size. The differences observed in egg size in all cases are rather small.

A number of workers including Jull, Parkhurst, and (according to Jull, 1932) Atwood and Clark, Thompson, Asmundson, and Marble present data indicating that egg weight and number of eggs laid in a year are independent entities. But the experience of breeders of heavy laying flocks indicates rather universally that egg size will decrease as the mean production of the flock increases unless careful attention is given to egg size. Hays (1929a) pointed out that very heavy winter laying in Rhode Island Reds is accompanied by small egg size. A number of other workers including Lippincott, Jull, and Parkhurst report that early sexual maturity, which is related to annual egg production, is associated with small egg size. Hadley and Caldwell, Atwood, Jull and Rynehart have substantiated the findings with Rhode Island Reds at this station — that heavy body weight is associated with large egg size.

In considering the question of breeding for large egg size, it becomes necessary to lay down certain standards for egg size. Hays (1929a) has assumed that pullet eggs weighing 56.7 grams each or 24 ounces to the dozen in February are satisfactory. On such a basis all eggs laid the first year will average about 23.5 ounces per dozen. Egg weight in such birds will increase about 7 per cent in the second laying year, or from 1.5 to 2 ounces per dozen.

Working on this basis, Hays (1929a) has reported two major genes as largely responsible for the differences in egg weight. Gene A produces an egg size in February of considerably less than 24 ounces per dozen; gene B alone gives an

egg weight of 24 ounces or more; when genes A and B are present in the same individual, the egg weight in February falls below 24 ounces. There are thus three general classes of birds with respect to egg size. The A class may lay 22-ounce or smaller eggs, the AB class will approximate 23 ounces, and the B class will lay eggs weighing 24 ounces or more. The breeding problem lies in the constant selection of pullet breeders laying 24-ounce or heavier eggs and yearlings laying 25.5- to 26-ounce eggs, and the constant use of males carrying the inheritance for large egg size.

The Selection of Superior Males

Selection of superior males for breeding has always been a troublesome problem. The reason is evident, because there are no measures of the male's performance with respect to the characters affecting egg production. Young males are selected either on the performance of their female ancestors or on the partial records of performance of their sisters. In the light of the many genetic factors concerned, it is evident that either method is very unreliable. Aged males may be selected on the performance records of their daughters, and satisfactory matings should be repeated. Even though progeny-tested males are used as far as possible, the system requires that at least three times as many males be used as cockerels each year as will be required for breeding when three years of age because of high mortality in males. Males must be at least three years of age before the fecundity records of their daughters are known. This fact greatly limits the use of this method with the medium breeds where the reproductive life of males is relatively short.

Since complete progeny testing has such pronounced limitations, a system of partial progeny testing has been suggested by Warren (1932). He recommends that cockerels for breeding be selected from families where the sisters show such desirable characters as early maturity, high intensity, etc., early in the season. This method is of some value in selection but falls far short of being an accurate method.

Unpublished data from the Massachusetts Experiment Station flock of Rhode Island Reds show that during the past five years only 3 (5 per cent) of the 60 males used have raised the mean egg production of the daughters over their dams. These males were mated to females laying from 226 to 250 eggs during their pullet year. Since the average egg production of birds in this experiment is 235 eggs, such dams are truly representative.

The method of evaluating males for breeding purposes which the authors believe to be genetically sound is based on the relative proportions of early maturing, non-pause, highly intense, non-broody, and highly persistent daughters produced by the males compared when mated to females carrying these characters. Thus individual males may be directly compared in their ability to transmit any or all of these five characters which are so vitally related to high production. By this method it is possible to use partially tested males with considerable confidence when they are two years of age rather than to wait until the male is three years of age. This method of selection has proved superior to any other method used to fix the five high fecundity characters in the flock. Under all conditions males can be compared on the progeny test only when each is mated to the same character of females.

The Introduction of Outside Stock

From the genetic standpoint almost any flock of birds is very heterogeneous, especially with respect to genes concerned in the inheritance of high fecundity. The fact has already been pointed out, however, that close inbreeding is detrimental to increasing the egg production as a rule. The method of improving the station flock has avoided inbreeding; at the same time, there has been no outside stock introduced since 1915. Under this system of breeding there arises a high degree of relationship which may eventually produce the same effects as close inbreeding. Limited experimental studies on the value of introducing outside production-bred males have given negative results so far.

Practical breeders desire to know how long they may continue breeding within their own flocks and what specific developments indicate that outside stock should be introduced. In answer to these question, experience here tends to show that there are two specific indications that new blood may be beneficial. (1) If hatchability is on the decline even though incubation methods are good and attention is given to hatchability in selecting breeders, it is probable that the stock is too closely related. (2) If there is excessive mortality in the families on the range and in the pullets during the first laying year from no specific disease outbreaks but largely from many functional disturbances, this is evidence of close relationship. Close inbreeding very often produces low hatchability and late sexual maturity as well as lack of persistency.

When there is evidence that outside stock is needed, it is especially important that such stock should be selected from flocks bred systematically for the characters being sought, and that the birds should be free from undesirable defects. Probably the most satisfactory procedure is to obtain pedigreed hatching eggs from two or three different sources and to hatch and rear the chicks with the regular flock. Pullets may then be housed with the home flock and trapnested until the hatching season to obtain some evidence of their behavior under existing conditions. Preliminary crosses can be made between those families that appear to be satisfactory, and the offspring checked against the home flock. Crossing should not be undertaken on too large a scale until there is evidence of its value, yet numbers should be sufficiently large to give a true measure of results.

The Types of Records Kept

One of the essentials in a successful breeding program is a complete and accurate system of records. Such records should be kept up to date and should be constantly used as a guide to the breeder. Trapnesting and record keeping are expensive and are of little value unless the records are studied and analyzed regularly. The two greatest essentials of a good set of records are simplicity and completeness.

The record forms used for the experimental flock are rather complete and are presented here not as suitable for commercial flocks, but rather as suggestive material to guide the breeder. It is easily possible to modify and combine these record forms to reduce labor and yet meet practical needs.

MASSACHUSETTS EXPERIMENT STATION—Hatching Record

0 O—INFERTILE 42 TOTAL EGGS SET
1 E—DIED EARLY 100 % FERTILITY
3 V—DIED LATE 86 % HATCHABILITY
36 π—HATCHED

XN—DEAD AT FULL TERM, NORMAL
XH—DEAD AT FULL TERM, HEMORRHAGE
XP—DEAD AT FULL TERM, ABNORMAL POSITION
2 XY—DEAD AT FULL TERM, YOLK NOT ABSORBED

YEAR 1933 PROJECT 2

FEMALE L34 MATE L2

INCUBATOR	DATE SET	DATE EGG						LAID WEIGHT		NUMBER SET	REMARKS
	2/11	π 1	π 2	π 4	π 5	π 8	π 10			6	
	2/18	π 11	π 12	π 14	π 15	π 16				5	
	2/25	π 18	π 19	π 21	V 22	XY 24				5	
	3/4	π 25	π 26	π 28	π 1	E 3				5	
	3/11	V 4	π 5	π 7	π 8	π 9				5	
	3/18	XY 11	π 12	π 14	π 15	π 17				5	
	3/25	π 18	π 19	π 21	π 22	π 23				5	
	4/1	π 25	π 26	V 27	π 28	π 30	π 31			6	

Figure 1.—Individual Hatching Record

There should be one small sheet for each female. The record includes date set, date on which each egg was laid, number infertile, number dying early, number dying late, and number of chicks hatched. At the close of the hatching season these data may be summarized for each female.

	Dam	Sire	Exp.	Feathering	Weight	Notes
♀ 501	L 2967	M 991	1	+	5.22	Light ear lobes, light red, black mottled
♀ 502			1	–	5.72	
♀ 503	L 2967	M 991	1	+	4.80	
♀ 504	L 2775	M 897	2	–	5.10	Black mottled
♀ 505			2	+	2.74	Pale and thin 8/16
♂ 506			2	–	5.28	Very light red
♀ 507			2	–	4.83	Light ear lobes
♀ 508			2	–		D 7/29
♀ 509	L 2775	M 897	2	–	4.80	
♀ 510	L 3003	L 646	2	+	4.95	
♀ 511			2	+		
♀ 512			2	+	4.90	Light red
♀ 513			2	+	4.76	
♀ 514	L 3003	L 646	2	+		Culled 7/25
♂ 515	L 2980	L 646	2	–	4.98	Very light red, slate
♀ 516			2	+		D 7/5
♀ 517			2	+		D 6/21
♀ 518			2	+		
♀ 519	L 2980	L 646	2	–		Very light red
♂ 520	M 159	M 2741	7	–	5.32	
♂ 521			7	–	5.00	
522			7			D 5/1
♂ 523			7	–	5.48	
♀ 524	M 159	M 2741	7	+	4.88	
♀ 525	M 399	M 1115	4	–	4.50	

Figure 2.—Double Page from General Record Book

A well-bound book with ruled pages about 5½ x 8½ is very convenient and may be purchased at any bookstore. Numbers may be stamped in consecutive order on the left side of each left page, and all the rest of the space to the right used for records. As the chicks are taken from the incubator they are banded and the mother's number placed after the chick's band number. These bands remain the permanent number of the chick.

Mating Sheet, Mass. Agr Exp. Station

7689 YEAR 1933 IM 6-29 No. 5947

PARENTAGE ♂ M2741 ♀ M2244 MATING DATES From To MATING NO. M2244

Chick Band No	♂	Date Hatched	EGG RECORD S	O	N	D	J	TOT.	Avg. egg wt. to ~~Pause Days~~ Jan 1	Chick ~~Broody Periods~~ feathering	~~MATINGS USED IN~~ NOTES
N 403	♀	Mar. 5	23	28	23	25			53.4 g	+	Blistered breast
404	♀	"			21	18			52.9	−	
405	♂	"								−	6.36 lbs. Breeder Bls. brst
406	♀	"		8	7	11			67.2	+	Lt. ear lobes
407		"	D	4/14							
408	♂	"								−	5.90 Br.
835	♀	Mar. 12	19	28	26	22			51.1	+	
836	♀	"	4	9	0	0			51.9	+	
837	♀	"	D	6/2						+	
838	♀	"	16	25	21	23			58.3	+	
839	♂	"	D	6/6						−	
1234	♂	Mar. 19								−	5.85 Br. Very lt red. Bls. brst
1235	♀	"	13	23	24	20			61.2	+	
1236	♂	"								−	5.25 Br. Wavy comb
1237	♀	"	12	28	26	17			51.0	+	
1238	♂	"								−	5.20 Br. Light red
1678	♀	Mar. 26	2	20	27	19			58.1	−	
1679	♀	"	4	22	29	20			53.5		Lt. ear lobes
1680	♀	"	6	24	25	13			52.6	−	
1681	♀	"	1	14	18	11			62.0	+	White in wings
1682	♂	"								−	5.40 Br. Bls. brst.
2166	♂	Apr. 2								−	5.85 Br. Bls. brst.
2167	♂	"								−	5.56 Br. Bls. brst.
2168	♂	"								−	5.12 Stubs
2169	♀	"	3	27	24	20			55.3	−	Lt. ear lobes
2605	♂	Apr. 9								−	4.97 Wavy comb, bls. brst.
2606	♂									−	5.08 Wavy comb, very lt. red
2607	♀	"		14	24	19			54.8	+	Lt. ear lobes
2608	♀	"		17	21	16			53.1	+	Lt. ear lobes
2609	♀	"								+	Lt. ear lobes
2941	♀	Apr. 16		14	25	19			52.3	+	Lt. ear lobes
2942	♀	"		7	26	23			50.7	+	Lt. ear lobes
2943	♂	"									
2944	♂	"									
2945	♂	"									

Figure 3.—Complete Mating Record

The mating book consists of loose sheets each 8⅜ x 10⅞ inches, held in a ring binder. At the close of the hatching season all chicks from each hen are entered on this sheet, which gives the sex, date hatched, the partial egg record for pullets, pause days, broody periods, and other notes taken. The disposal of pullets and cockerels is also recorded on this sheet along with the mortality records.

Male J347 Exp. 2

No.	Date Hatched 1931	Age at 1st. Egg	Wt. at 1st. Egg	Winter Pause Days	Winter Clutch	Eggs to Mar. 1st.	Egg Wt. to Jan. 1	Time to St. Egg Wt.	Spring Clutch	Persistency	Times Brody	Annual Prodctn	Notes
J1363	Apr 7 1929	184	4.20	0	3.7	108	54.5	75	5.0	365+	0	273	
L26	Mar. 27	163	5.75	0	4.5	137	51.5	202	3.1	366+	5	243	
L28	Mar 29	167	4.45	0	4.7	139	51.3	—	4.1	326	0	258	
L30	Mar. 29	157	4.77	0	4.5	140	49.7	—	5.2	366+	0	274	
L631	Apr 5	202	5.95	0	4.6	106	54.3	81	3.8	366+	0	300	
L632	Apr. 5	234	5.90	0	1.9	64	60.1	0	2.5	335	0	219	
L1026	Apr. 12	185	5.60	34	2.9	78	54.8	24	2.4	366+	2	200	
L1027	Apr 12	187	5.40	0	6.2	118	55.6	3	3.9	261	0	258	
L1028	Apr. 12	165	4.82	0	2.8	118	55.6	5	3.6	366+	0	270	
L1434	Apr. 19	195	6.75	6	4.9	93	54.9	38	6.0	366+	0	256	
L1436	Apr 19	186	5.90	4	4.2	104	54.8	20	2.6	366+	0	257	
L1822	Apr. 26	172	6.15	0	6.5	118	52.3	88	6.4	366+	1	282	
L1825	Apr. 26	192	6.50	9	2.4	78	54.6	177	2.7	345	0	229	
L2697	May 10	175	5.08	0	4.8	100	55.0	56	3.3	366+	1	262	
L2698	May 10	167	6.20	0	4.3	100	52.5	149	4.4	366+	0	271	
L2699	May 10	194	5.95	35	3.8	60	55.3	34	5.5	366+	0	260	
L3034	May 17	236	7.00	0	2.8	36	—	—	—	—	—	—	D Apr 1
L3038	May 17	179	5.75	0	5.3	93	54.7	96	3.5	366+	0	264	
No. dau.		17	17	5+	17	17	16	14	16	16	4+	16	
Average.		185.6	5.76	12−	4.2	98.9	54.2	69.5	3.9	353.7	12−	256.4	

Figure 4.—Pullet Family Record.

When the pullets are housed in the fall, the laying-house record sheets are made. Sheets 8½ x 11 inches are used, and as many families as space will permit placed on each sheet, with the sire's number at the top of the sheet. Complete records on characters affecting fecundity are recorded for each daughter throughout the laying year.

MASSACHUSETTS AGRICULTURAL COLLEGE—Daily Egg Record

PEN NUMBER 2 MONTH OF March YEAR 1933 ATTENDANT

N—ON NEST BUT DID NOT LAY X—BROKEN EGG D—DIED F—FLOOR NESTING L—REMOVED A—RETURNED LO—MOVED TO SUMMER HOUSE M—MOULT C—CLUCKS B—BROODY DB—DROPPING BOARDS

Female's Numbers	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Remarks
M1489	10		7	10	11	4		9	9	9	2		8	1																			
1490	25	3		9	10	2	3		8	8	10	2	4x		8	10	3		8	11	3		8	10	11	1		7	9	10	10	10	
1509	26	7	8	9	10	10	1	3		8	9	11	2		8	8	8	9	9	9	10	9	8		1		9x	9	8		8	7	
1549	22	8	2x		8				1		8	2		8	1		8	8	9	10	10	10	1		7	10	8	1		8	9	10	
1550	4	10	2		9	10																											
1554	30	7	8	9	9	10	10	11	10	10	10	11	9	11	11	2	11	11	10	11	10	10	11	10	11	11	10	10	10	11	1		
1567	23		7	9	11	5		8	9	10	3		7	9	10	10	1	3		8	9	10	11				8	11	4		7	9	
1568	1						10																										
1571	28	9	10	9	9	9	9	9	9	1		9	8	9	9	9	9	9	11	3		8	8	10	11	1x		7	7	7	7	7	
1576	19	9	9		9	9	9		11	5		8		3		9	9	3		8	9	1		10			3			3		9	
1578	27	10	10	10	9	8	9	11	10	11	10	11	4	3		8	8	9	9	10	9			5		7	8	8	10	9	10	10	
1579	29		8	9	9	9	9	9	9	9	9	9	9	9	10	9	9	9	9	10	9	9	10	10	10	9	8	8	1		7	8	
1581	11	11	11	3		8	10	1			8	8	9	9																	9		
1582	22	11	11	3		8	9		9			8	9	10	11	11	1					8	9	10	10	10	11	1		7	8	9	
1583	27	9	11	10		11	10	10	1			10	9	10	10	11	11	11	1		10	11	11	11	11	10	10	10	10	10	9	8	
1585	24	10	10	11	11	2		8	10	11	2		7	8	10x	2		8	10	11	1		7		9	11	2		8	10	1		
1588	23	11	2		8	11	1		8	10	2		8	1		8	1	1		8	1	4		7	10	1		8	11	1		10	18 Weak Wattles + comb back
1589	—	9	2		9	9		9												D													
1592	26		8	9	11	11	1	3		8	8	9	9		9	9	9	9	1	4		7	7	10	10	10	10	11	1		7	9	
1593	25	11	2		9	8	9	10	11	3		9	9	10			9	10	11	1	11	1		8	10	1		7	8	10	10	10	
Unidentified Eggs																																	
TOTALS																																	TOTALS

Figure 5.—Trapnest Record

The trapnest sheets used are 9⅝ x 15 inches, with space for 20 birds. Each alternate line is heavy, to guard against errors in putting in trapnest records. A record is kept of the hour of laying, nesting, broken eggs, death of bird, floor nesting, removals, returns, sales, removal to summer houses, molt, clucking, broodiness, and eggs laid on dropping boards. The body weight at first egg is also recorded and notes regarding injury or disease.

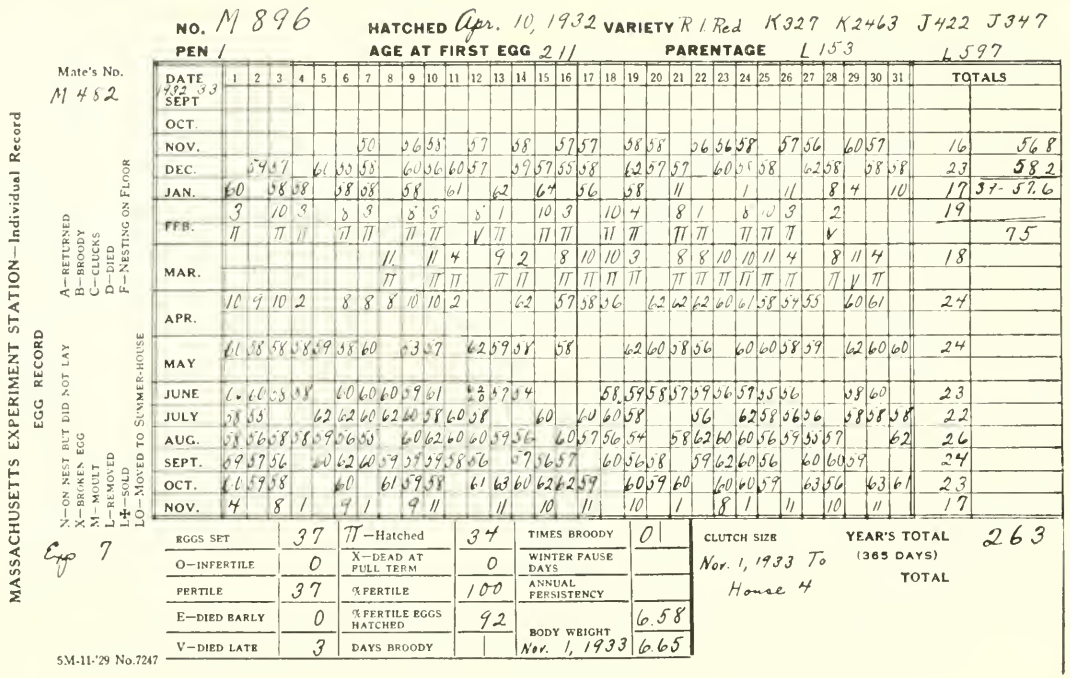

Figure 6.—Individual Record Sheet

These sheets are 5 x 8 inches and include a complete egg record of each female, together with egg-weight records and hatching record. These records are especially valuable in studying the characters of the individual in detail, and make a direct comparison of individuals possible.

The Breeding Procedure Recommended for Increasing Egg Production

Egg production of each succeeding generation in the flock can be increased only by using a superior class of breeding stock to produce each generation. The outstanding experiment to support this view was carried on by Gowell at the Maine Agricultural Experiment Station with Barred Plymouth Rocks. The detailed results in relation to egg production are reported by Pearl and Surface (1909a and b) and by Pearl (1911). Each year Gowell selected for breeding yearling hens with records of 150 or more eggs in the pullet year. Each year these hens were mated to cockerels from mothers laying 200 eggs or more. All daughters were trapnested from November 1 to October 30 each year. The standard for breeders was not raised as the experiment progressed. The mean annual egg records of the daughters hatched from 1899 to 1906 were 136, 143, 156, 135, 118, 134, 140, and 113 in the respective years. The variation in annual production did not decline and there was actually a significant decline in egg production of daughters in the eight-year period. A very great decrease was observed in winter egg production during this period, the means ranging from 41 eggs in 1899 to 16 eggs in 1907.

Pearl and Surface (1909a) hatched 250 pullets from hens that had laid 200 eggs during their pullet year. These pullets were sired by cockerels whose female ancestors had laid not less than 200 eggs for seven generations. These pullets were trapnested from November 1 to July 1 and compared with 600 pullets from the line previously developed by Gowell. The mean winter production of the first group of pullets was about 16 eggs compared with about 19 eggs for the second group. The notation is made by the authors that the pullets from 200-egg dams were inferior to those of the other group. It is very evident, in view of modern information, that neither method of selection of breeders was rigid enough to increase the production of the daughters.

Marble and Hall (1931) report results in breeding high- and low-producing lines of White Leghorns. The mean annual egg production of the high line was raised by careful breeding from 127 eggs in 1908 to 196 eggs in 1927. Egg weight and body weight did not decrease, and length of cycle increased as egg production increased. Mean age at first egg did not change significantly after ten or eleven years of breeding.

Lippincott (1920) mated three lines of mongrel pullets and their daughters to purebred cockerels and one line to mongrel cockerels for three generations, with the following results:

Average Percentage of Increase or Decrease in First-Year Egg Production of Each Generation of Offspring Compared with the Original Mongrel Pen

	First Generation	Second Generation	Third Generation
Single Comb White Leghorn Grades	115.62	160.85	166.39
Barred Plymouth Rock Grades	34.51	51.87	57.97
White Orpington Grades	49.52	24.76	−6.13
Mongrels	8.55	51.56	35.28

These data show that mongrel flocks may be greatly improved in egg production through the use of purebred males from flocks improved for production.

Extension projects in flock improvement carried on by the Massachusetts Agricultural Extension Service show very definitely that the egg production of ordinary flocks may be greatly increased through the use of outside males from flocks highly improved for egg production.

A method of breeding within the flock that will raise the mean annual egg production from 114 eggs to 235 eggs in twenty years without any culling in the laying houses may be considered rather satisfactory. Such a result has been accomplished in the Massachusetts Station flock using the system outlined below. As previously indicated the flock was started by purchasing mature pullets from two different sources, and males that were not closely related to the pullets were obtained from one of these flocks. The foundation stock was not improved for fecundity but represented improved breeding from the exhibition standpoint. These birds were late maturing, low in intensity, high in broodiness, and not persistent layers.

Early in the history of the flock it was decided by Goodale after much study that selective breeding to be effective must be based not upon egg records as a unit but upon inherited characters that directly affect egg production.

The first character bred was for early sexual maturity. Female breeders that began to lay at the youngest age were made use of and mated to males whose sisters had laid earlier than the average. The fourth generation, hatched in 1916, showed the character of early maturity to be rather well established, with a flock mean of 213 days. Since that time only early-maturing females have been used, and the flock mean age has fluctuated between 185 and 210 days.

Genetically early-maturing birds begin laying at 215 days of age or younger. On account of the advantages of large size so intimately associated with egg size, the selection of extremely early-laying breeders has been avoided. In recent years preference has been given to females that began laying at from 200 to 210 days of age.

The elimination of broodiness in the flock was undertaken next, without sacrificing any progress in breeding for early maturity. Progress was made by selecting as many female breeders as possible that were free of broodiness in the pullet year. This was followed by the exclusive use of male breeders from this class of dams. Some males and females tested for non-broodiness were made use of from time to time. Selection has since been based on the greatest freedom from broodiness within the family. As previously indicated, the percentage of individuals broody in the first laying year has fallen from 90 per cent to about 11 per cent.

Intensity of laying or the ability to lay a large number of eggs in a specific time interval was the third character to be considered in improving the flock. This character was established largely through one female and her descendants. Since high intensity depends upon dominant genes, it was not necessary to practice close inbreeding to establish the character. In the early part of the experiment breeding females were selected for the ability to lay a large number of eggs up to March 1, or for the ability to lay many eggs (26 or more) in a winter month like December. In recent years intensity has been measured by mean winter clutch size. A clutch represents the number of eggs laid on successive days, and the average size of clutches from first pullet egg up to March 1 gives

a measure of the rate of functioning of the egg-producing organs. Winter clutch size has increased from under two to about three and one-half at present. For holding high intensity no breeders showing a winter clutch size under three should be used.

Winter pause may be reduced by the constant use of breeders free from this undesirable character. The system of management, housing, and feeding should be the most favorable at all times.

High persistency has been the last character to be developed in the station flock. Through the selection of female breeders that lay late in the fall and of yearling breeders that have laid for as much as thirteen or fourteen months, mean flock persistency has been raised from about 250 days to about 340 days at present. No breeder with a persistency record of less than 315 days from first egg should be used. A recent study shows clearly that the ability to lay for more than 365 days is highly desirable in breeding birds.

Persistency is linked in inheritance with early maturity. For this reason it is very advantageous to select early maturing and persistent birds early in the breeding program. The ultimate goal is a flock breeding true for these five desirable fecundity factors as well as for desirable breed characters and free from all recognized defects.

From what has gone before it is evident that such a breeding program should not be attempted on a small scale. Only breeders that handle relatively large flocks can hope to make consistent progress from year to year.

The ideal hen is of very complex genetic nature and the probability of obtaining any significant proportion of such individuals is very remote in small flocks. As far as present information is concerned, the genetic formula of an ideal breeding hen is essentially as follows: EoE′E′III′I′mmaaccPPaaBBHH. In this formula the known genes for early sexual maturity, high intensity, no winter pause, non-broodiness, high persistency, large egg size, and high hatchability are considered.

The following standard has been used in selecting female breeders in the Rhode Island Red flock at the Massachusetts Station:

Age at first egg	215 days or less.
Weight at first egg	5.5 pounds or more.
Intensity (winter clutch size)	3 or more eggs.
No winter pause of more than 3 days.	
No broodiness.	
Persistency	315 days or more.
Egg size	Not under 24½ ounces for pullets. Not under 26 ounces for hens.
Laying-house mortality	Not over 15 per cent.

The standard should be raised as the work progresses.

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Publication of this Document Approved by Commission on Administration and Finance 4M-4-'34. No. 1137.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 308 May, 1934

Preliminary Studies on Neurolymphomatosis and Some More or Less Related Diseases

By Charles S. Gibbs

A group of poultry diseases, many probably of an infectious nature, are taking a heavy toll from Massachusetts flocks. It is conceivable that most of these disorders may be controllable if properly understood. This investigation was undertaken to determine some of the fundamental characteristics and causes of so-called "fowl paralysis" which is rapidly becoming economically very significant.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

PRELIMINARY STUDIES ON NEUROLYMPHOMATOSIS AND SOME MORE OR LESS RELATED DISEASES

By Charles S. Gibbs,[1] Research Professor of Veterinary Science

Neurolymphomatosis, generally referred to as "fowl paralysis," is quite common in the United States and Europe, and has been recognized in Massachusetts since Kaupp (1921) and Pappenheimer (1926) described it. All breeds of chickens are susceptible, but turkeys, geese, ducks, other poultry, and wild fowl are not known to be affected. Ordinarily, it is a disease of pullets and cockerels of three to eight months of age, and the heaviest losses usually occur in the late summer and early fall, although there are exceptions to this rule.

The most noticeable symptoms are paralysis of either one or both legs or the wings, and blindness marked by a greyish appearance of the eye. The comb and wattles are usually of normal color, and the birds have a good appetite as long as they are able to eat. The symptoms may appear suddenly or gradually, and the birds may die in a few weeks, or the condition may be prolonged over a period of several months. Very few cases of neurolymphomatosis ever recover.

Diagnosis is usually made by observation of the disease in a flock and by necropsy of dead birds. A definite technique for the macroscopic diagnosis has been worked out by Jungherr (1933). The lesions are located in the nervous system and contiguous tissues, such as the blood, visceral organs, muscles, etc. Since the tissue changes are very difficult to recognize in some cases, the history of the outbreak, the symptoms of the sick birds, and the general appearance of the flock are of great aid in differentiating neurolymphomatosis from some other diseases and obtaining a satisfactory diagnosis.

The real cause of neurolymphomatosis is unknown. There have been considerable speculation and some laboratory study on this phase of the disease, but without any definite conclusions. In other words, to determine the etiology of neurolymphomatosis, the investigator should have at his disposal a well-equipped laboratory and a poultry plant with facilities for hatching and isolation of different groups of birds. The cost of such an undertaking has, up to the present, precluded any satisfactory demonstration of the etiological agent.

Etiology

Attempts to transmit neurolymphomatosis in this study have not been uniformly successful. In all, 400 chickens have been inoculated subcutaneously, intramuscularly, intraperitoneally, and intracranially with neoplastic suspensions of diseased nerves and tumor tissue in physiological saline solution without showing any symptoms of disease. Also 400 uninoculated controls from the same flocks and reared under the same conditions did not reveal any lesions of either neurolymphomatosis or lymphocytomatosis at necropsy. In addition, 60 chickens

[1]The writer extends his sincere thanks to Oliver S. Flint, Department of Veterinary Science, Massachusetts Agricultural Experiment Station, for doing the photographic work for this bulletin; and to the Poultry Department of the College and Experiment Station, which made this study possible.

were inoculated intravenously with Berkefeld V filtrates of the neoplastic lesions of nerve tissue, which had been ground up in a sterile mortar with a sterile pestle and sand. Also, fresh lymphocytomas were transplanted into the visceral organs, muscles, and skins of 140 chickens, by means of a sterile trocar. These chickens were held for six months without showing any symptoms or lesions of lymphocytomatosis, a disease closely related to, if not the same as, neurolymphomatosis.

The stock for these etiological experiments was selected from 10 different flocks and an attempt was made to avoid chickens previously exposed to the disease, as such exposure might lead to erroneous results. Active symptoms of neurolymphomatosis do not appear for two or three months after infection has taken place. This precaution was deemed necessary because in some of the earlier experiments of the writer the same number of controls as inoculated birds came down with symptoms and lesions of neurolymphomatosis, indicating that the birds had previously contracted the disease.

Also it was found in the course of these experiments that chickens inoculated intraperitoneally and intramuscularly with suspensions of neurolymphomas, pyogenic bacteria, and tar developed tumors of the peritoneum, visceral organs, mesentery, muscles, celiac plexus, and small nerves of the visceral organs indistinguishable from lymphocytomas and neurolymphomas of spontaneous origin. Ruptured egg sacs and oviducts were believed to be responsible for similar conditions in spontaneous cases by first establishing peritonitis, which ultimately led to tumor formation.

The results of these laboratory transmission experiments are inconclusive, and in view of the work that has been done by Seagar (1933), Lerche and Fritzsche (1933), and McIntosh (1933) should not be considered final until further work has been done, because there are so many unknown factors associated with the etiology of neurolymphomatosis and lymphocytomatosis that it is doubtful whether any investigator has succeeded in keeping them all under control. However, persistent trial and error, of which this study is a beginning, should not only reveal the etiology of these two diseases but show their relation, if any, to lympholeukosis.

The Development of Histological Methods

Plenty of material from spontaneous cases has been available for hematological and histopathological studies. It has been possible to select material from flocks of which the history was known, and the studies for the most part have been confined to one of these flocks for a period of four years. The first two years were devoted largely to developing staining methods, acquiring a familiarity with the histological elements in poultry pathology, and differentiating neurolymphomatosis from other diseases to which it appeared at first to be more or less related in spontaneous cases.

The blood staining methods suggested by Furth (1931), the bone marrow studies of Forkner (1929), and Mallory's (1921) eosin and methylene blue and phosphotungstic acid hematoxylin stains for tissues were especially valuable in the development of histological methods for this study. Wong's (1928) method for the determination of hemoglobin was used. The blood clotting time was estimated by the method of Wright (Morse and Looney, 1927).

It was found that the thrombocytes could not be counted with any degree of accuracy unless supravital staining was employed. Hence the counts for thrombocytes are omitted in this bulletin.

The Pathological Cell in Neurolymphomatosis and Lymphocytomatosis

First comparative studies were made of normal birds and those showing neurolymphomatosis with gross lesions, avian paralysis without gross lesions, myeloleukosis, erythroleukosis, and lymphocytomatosis. In distinction from Patterson et al. (1932), little difficulty was experienced in differentiating neurolymphomatosis from erythroleukosis and myeloleukosis, while lympholeukosis appeared to be closely related. The large lymphocyte observed in the infiltrated nerves of neurolymphomatosis, Fig. 1, appears to be similar to the pathological cell found in lymphocytomatosis, as stated by Matthews and Walkey (1929).

In this study there was evidence of perivascular infiltration in which the pathological cells passed in the blood and lymph until they filled the spaces between the nerve fibers, as shown in Fig. 2. The walls of the arteries and veins were

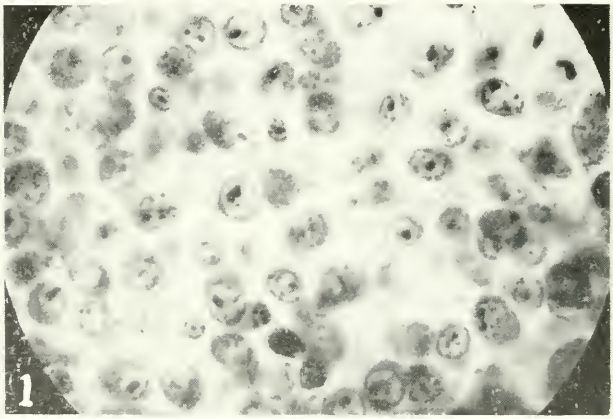


Figure 1. Pathological Cells in Neurolymphomatosis, showing the division of the nucleus and the characteristic concentric arrangement in some cells. (Magnified 1100 diameters.)

Figure 2. Infiltration of Pathological Cells around Nerve Fibers. (Magnified 100 diameters.)

not destroyed, and the nourishment in the vascular system was diverted from the nerve fibers to the pathological cells, which appeared to increase very rapidly by further infiltration and mitosis until all of the neutral staining tissues were replaced by basic staining neoplastic cells. In other words, the nerve fibers appeared to die for the lack of nourishment and were finally dissolved and carried away by the blood stream, as the pathological cells at first surrounded them and later replaced them entirely. This is the physiological development of the neurolymphoma in the nerve of the fowl as observed histologically in these studies. Enzymes may have played a part in the destruction and absorption of the nervous tissue, but their presence could not be demonstrated in either living or dead tissues.

This tumor-like growth of the nervous system is what Pappenheimer et al. (1929) have called a neurolymphoma, and it leads to the pathological condition called neurolymphomatosis by Johnson (1932). These names are retained in this study and have already been used several times. Since the neurolymphoma tissue cannot be stimulated like nervous tissue, it naturally follows that muscles, organs, and other structures supplied by nerves suffer as a result of interference in normal functions, and symptoms of disease arise.

Figure 3. Lymphocytoma of the Gizzard.
Left, diseased gizzard.
Right, normal gizzard.

The fact that the neoplastic cell involved in neurolymphomatosis has been found in the blood and lymph shows that there is ample opportunity for it to find its way into the general circulation and be involved in metastatic conditions. Metastasis, as well as infiltration, has been found in this study and will be pointed out a little later.

Before proceeding further it is necessary to indicate that the neurolymphoma resembles the lymphocytoma in physical appearance and consistency, as well as in possessing the same type of pathological cell. Both develop from incipient perivascular infiltrations into the tissues. In advanced cases the neurolymphoma is usually smaller than the lymphocytoma. This is probably due to the fact that the blood and lymph spaces in the visceral organs and muscles are larger than in the nervous tissues, and growth proceeds more rapidly because more cells are able to crowd in and nourishment is more readily brought to them. Lymphocytoma of the gizzard is shown in Fig. 3. In advanced cases of lymphocytomatosis, in which the neoplasms had reached comparatively large sizes, anemia was present. Neurolymphomatosis was never accompanied by noticeable symptoms of anemia unless the birds were so paralyzed that they could not reach

feed and water, or nerves supplying the digestive system were affected and malnutrition had set in.

In some cases lymphocytomas were found completely surrounding nerve trunks without showing any evidence of invasion, as stated by Matthews and Walkey (1929). On the other hand, many cases of avian paralysis were found in which visceral organs, muscles, the integument, and nervous tissue were simultaneously involved. In some of these cases the diseased condition appeared to have spread by infiltration and in others metastasis had apparently taken place through the blood stream. The infiltrations were continuous and involved contiguous nerves and organs. The most common simultaneous infiltration of nervous tissue and visceral organs occurred in the celiac plexus, ovary, and adjacent structures, with the vagus nerve and thymus glands next. The common invasion of the sciatic nerve and kidney was found in 10 cases from the same flock. It appeared from histological examination of diseased tissues that a common pathological cell was involved in both nerves and visceral organs, as appears in Fig. 4. This finding is in agreement with that of Biely, Palmer, and Lloyd (1933).

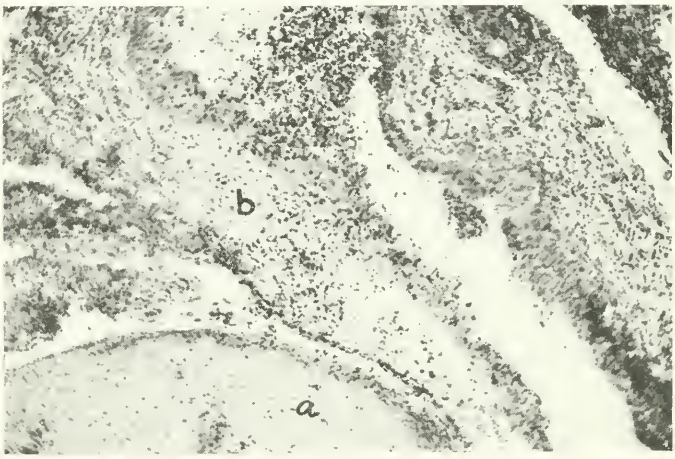


Figure 4. Neurolymphoma of Sciatic Nerve (a) and Lymphocytoma of the Connective Tissues and Surrounding Muscles (b). (Magnified 100 diameters.)

Neurolymphomatosis

In general, it cannot be stated that any particular nerve or plexus is more susceptible to invasion than another because neurolymphomas were found in all of the nerves of the fowl, and two birds were found in which every motor nerve in the body appeared to be affected. These two birds were in a most helpless condition. Paralysis is especially evident when the sciatic nerves, brachial plexus, celiac plexus, vagus, and optic nerves are involved because important functions of the body are interfered with, and the lesions are more evident at necropsy in large nerves than in small ones. A careful checking up on the location of the gross lesions of neurolymphomatosis in the flocks studied did not reveal any outstanding flock specificity, such as might be attributed to family weakness or inherited predisposition, although such may have existed and our observations

were not fine enough to detect them. It was physically impossible to examine all of the birds histologically. Table 1 shows the results of the necropsies of 304 birds from seven different flocks and the tabulation of the names of the nerves affected with neurolymphomas.

TABLE I. LOCATION OF NEUROLYMPHOMAS

	Flocks						
Nerve	A	B	C	D	E	F	G
Sciatic	41	69	31	8	23	20	13
Vagus	39	35	30	6	14	27	12
Brachial	29	28	12	3	20	19	5
Celiac	12	3	9	4	7	15	10
Optic	6	4	0	0	0	0	16
Mesenteric	5	4	2	1	0	8	3
Crural	1	1	3	1	3	7	1
Peroneal	3	0	0	0	0	0	0
Costal	0	0	0	1	0	0	0
Cervical	0	1	0	0	0	0	0
Plantar	1	0	0	0	0	0	0
Laryngeal	2	0	0	1	1	4	0
Meningeal	1	0	0	1	0	0	0
Coccygeal	0	0	1	0	1	0	0
Number of Birds	91	92	32	10	25	30	24

This table shows that the sciatic, vagus, brachial, celiac, and optic nerves were most commonly affected. A comparison of Flock A with Flock F shows some important differences. In Flock A the sciatic nerves were most commonly involved, while in Flock F the involvements occurred largely in the vagus and brachial nerves. This may indicate flock specificity, but it cannot be definitely proved for all of these flocks represent different blood lines and the distribution of the neurolymphomas are rather uniform, except in Flock F referred to above, and Flock G, in which the optic nerve was frequently involved.

It was noticed that birds received from flocks on the range often improved after being isolated in individual cages. Histological and hematological examinations of the tissues and blood indicated that these birds were holding their own, temporarily at least. The pathological cell involved in neurolymphomatosis was not found in the blood and tissues outside of active lesions, which indicates that there was some antagonism to the disease. There was no laboratory evidence to indicate that this antagonism was due to immunity. The disease tends to lessen in severity after existing in a flock for two or three years, which demonstrates clinically that either some degree of immunity is developed or the susceptible birds die, leaving the more resistant to reproduce future generations. Three birds, apparently showing active symptoms of paralysis, recovered and at necropsy no lesions of disease were found.

Lymphocytomatosis

A study of uncomplicated lymphocytomatosis revealed that visceral organs, such as the ovary, mesentery, kidney, liver, and spleen were most commonly involved. These organs are closely associated with serous membranes. Next to be affected were organs and surfaces lined with mucous membranes, such as the peritoneum, oviduct, proventriculus, lungs, pleura, intestine, crop, ureter, and cloaca. Muscle tissue, skin, and ductless glands were involved in a few instances, showing that no tissue of the fowl is entirely resistant to lymphocytomatosis.

The lymphocytoma develops the same as the neurolymphoma, except that it is confined almost entirely to tissues other than the nervous type. The invading cell is indistinguishable from the pathological cell occurring in neurolymphomatosis. Parenchymatous organs, mucous membranes, and glandular tissues offer less resistance to invasion than muscle, or the integument.

Studies on the location of lymphocytomas are recorded in Table 2.

Table 2. The Location of Lymphocytomas

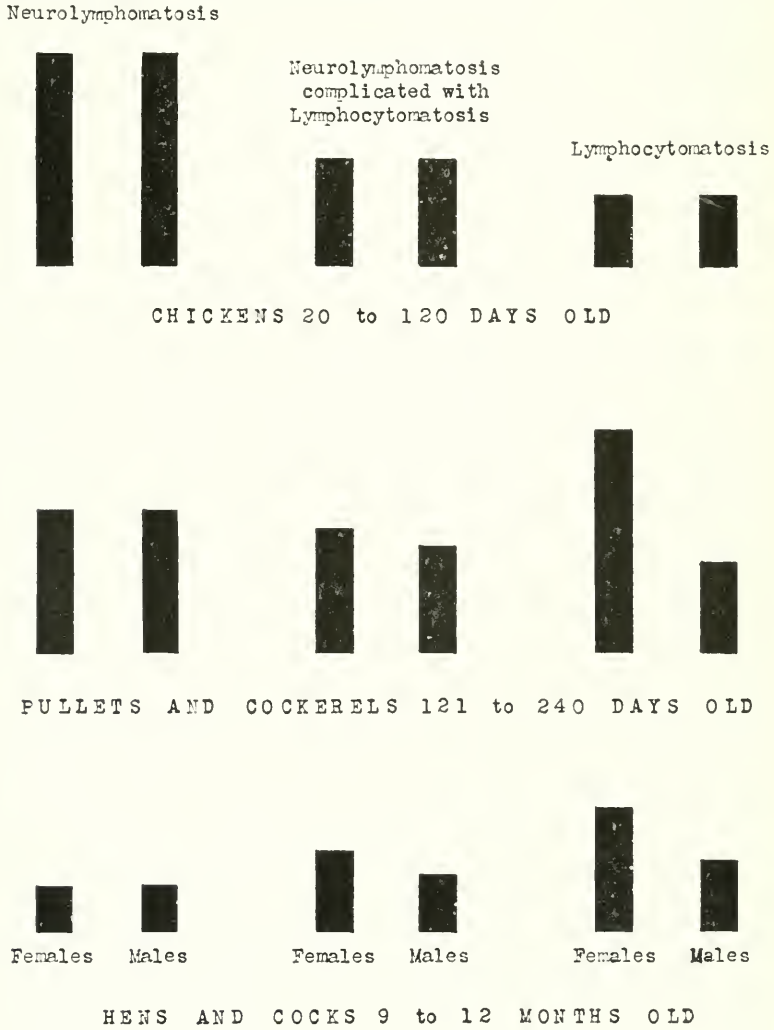
	Flocks						
Tissue	A	B	C	D	E	F	G
Ovary	21	19	3	2	6	8	4
Mesentery	12	15	5	1	3	3	2
Kidney	9	14	0	0	2	1	1
Liver	7	8	0	0	1	2	0
Peritoneum	8	8	0	2	4	0	0
Proventriculus	6	1	1	0	2	0	2
Pancreas	3	4	2	2	0	0	0
Muscle	4	4	0	0	1	0	0
Skin	6	4	0	1	3	1	0
Oviduct	4	5	0	0	1	4	2
Spleen	0	3	1	1	2	1	0
Pleura	1	2	0	0	1	0	1
Heart	1	1	0	1	0	0	0
Intestine	2	0	1	2	0	0	0
Thymus	1	0	0	1	0	0	0
Duodenum	0	1	0	0	1	0	0
Crop	1	0	0	0	0	0	0
Adrenal	1	0	0	0	1	0	0
Gizzard	1	0	2	1	3	0	0
Eye	0	1	0	0	1	0	0
Ureter	0	0	1	0	0	0	0
Cloaca	0	0	1	0	0	0	0
Number of Birds	33	55	8	5	15	16	8

This table shows that the ovary, mesentery, kidney, liver, peritoneum, and glandular portion of the proventriculus are especially susceptible to lymphocytomatosis. The disease is most common at the age of laying the first egg, which indicates that if irritation is not the sole cause it is at least a contributing factor.

Since lymphocytomatosis is more common in laying hens than it is in pullets, cockerels, and roosters, it may be that concentrated feeding and forced laying are important factors in the incidence of this disease.

Richardson (1933) has suggested "that catarrhal enteritis with extensive desquamation of the epithelium covering the villi is the primary lesion, with subsequent absorption of toxins from the digestive tract, causing a hyperplasia of the lymphoid tissue normally found in the various organs" may be responsible for the tumors in lympholeukosis, which are similar, if not the same, as in lymphocytomatosis. Lymphocytoma of the ovary is shown in Fig. 5.

Chart 1 represents the incidence of neurolymphomatosis, lymphocytomatosis, and neurolymphomatosis complicated by lymphocytomatosis at various age periods in the chicken, pullet, cockerel, hen, and cock.



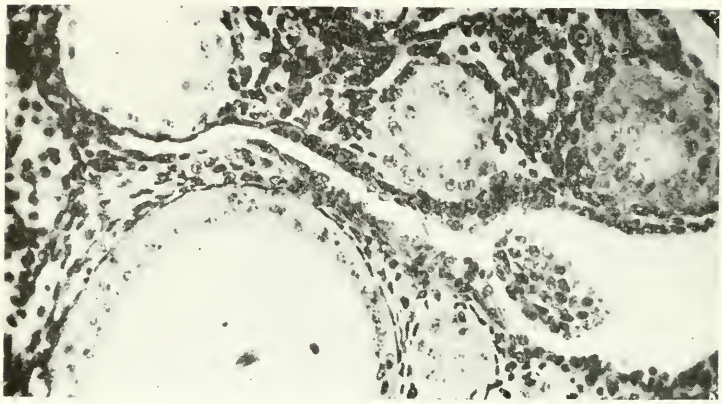


Figure 5. Lymphocytoma of the Ovary. The pathological cells show as black spots in the photograph. (Magnified 420 diameters.)

Neurolymphomatosis Complicated by Lymphocytomatosis

The hepatic, splenic, renal, ovarian, gastric, and small nerves were rarely affected unless neurolymphomatosis was complicated by lymphocytomatosis. Of the large nerves, the celiac plexus was most commonly involved with neurolymphoma as the ovary in the same bird was affected with lymphocytoma. The vagus, sciatic, and brachial nerves were affected by neurolymphomas which had apparently spread either by metastasis or direct infiltration to muscles of the legs, wings, thymus and thyroid glands, and visceral organs. Small lymphocytomas were found embedded in the skin or located in the subcutis immediately under it in 19 of the birds. The tumors were easily felt on palpation as irregular nodular masses. Some of these tumors were located on the breast and exposed to irritation when the birds were on the roosts, but ulceration was not found in any of them.

Representative tumors were studied histologically to see if the nerves supplying the skin were involved also, and they apparently were for all tissues within the infiltrated areas had been converted into tumor cells.

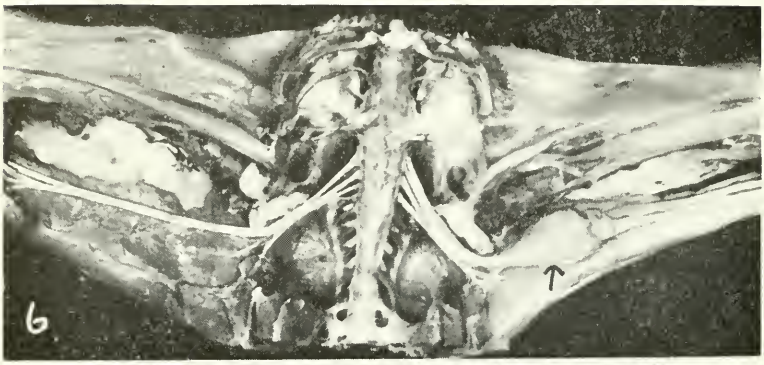
Neurolymphomatosis was complicated with lymphocytomatosis in Flocks A, B, C, and D and the results appear in Table 3. No complications of neurolymphomatosis and lymphocytomatosis occurred in Flocks E, F, and G and the results of the studies of these flocks appear in Tables 1 and 2.

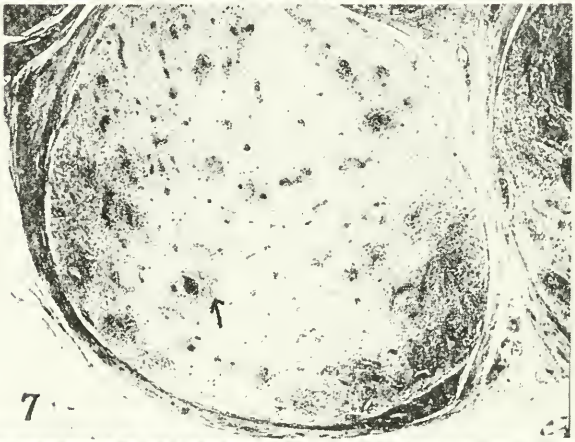
Table 3 shows that in Flock A neurolymphomas were confined largely to the celiac plexus and ovarian nerve, and the lymphocytomas to the ovary. In Flock B the neurolymphomas were found mostly in the vagus nerves while the greatest number of lymphocytomas appeared in the thyroid glands, the thymus glands, liver, spleen, and skin. In Flock C the neurolymphomas occurred mostly in the celiac plexus, and the lymphocytomas were few and not confined to any particular group of organs or tissues. In Flock D the greatest numbers of neurolymphomas were equally divided between the celiac, sciatic, and brachial plexus, and the largest numbers of lymphocytomas were about equally divided between the ovary and muscles of the legs and wings.

TABLE 3. THE LOCATIONS OF NEUROLYMPHOMAS AND LYMPHOCYTOMAS IN FOUR FLOCKS

Tissue	Flocks			
	A	B	C	D
Ovary	19	9	2	9
Celiac plexus	18	4	5	10
Vagus nerve	10	16	1	7
Sciatic nerve	7	8	1	10
Ovarian nerve	15	6	4	10
Brachial plexus	6	5	0	10
Mesenteric nerve	5	2	0	5
Mesentery	1	0	0	0
Crural nerve	4	0	0	0
Kidney	3	3	1	2
Renal nerve	1	1	1	2
Muscle	1	3	1	16
Thyroid	2	15	0	0
Thymus	0	12	0	0
Skin	1	15	0	3
Liver	1	14	1	1
Hepatic nerve	0	5	1	1
Spleen	0	15	1	0
Splenic nerve	0	7	1	0
Optic nerve	1	0	0	1
Lung	0	1	0	0
Pulmonary nerve	0	1	0	0
Peritoneum	0	1	0	0
Peroneal nerve	1	0	0	0
Testis	1	0	0	0
Gizzard	0	0	0	1
Proventriculus	2	0	0	1
Gastric plexus	1	0	0	1
Pancreas	1	0	0	0
Cervical nerve	0	0	0	2
Intestine	0	1	0	0
Number of Birds	25	17	5	17

In Flock A direct infiltration appeared to have occurred between the neurolymphomas of the celiac plexus and ovarian nerves, and the lymphocytomas of the ovary. The other neurolymphomas and lymphocytomas were apparently of metastatic inception. In Flock B direct infiltrations had apparently occurred between the neurolymphomas of the vagus nerves and the lymphocytomas of the thyroid and thymus glands. The neoplasms of the liver, spleen, skin, and other tissues were apparently of metastatic origin, as perivascular infiltration was demonstrated histologically in all of them. In Flock C the neurolymphomas





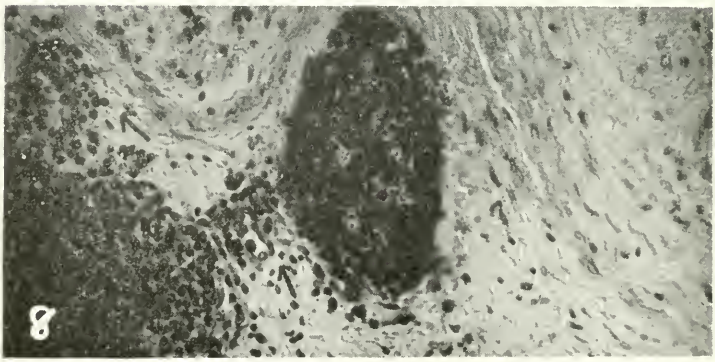


Figure 6. Neurolymphotomatosis of the Right Sciatic Nerve.
Figure 7. Perivascular Infiltration in Sciatic Nerve. (Magnified 200 diameters.)
Figure 8. Perivascular Infiltration in Sciatic Nerve. (Magnified 420 diameters.)

of the celiac plexus and ovarian nerve appeared to be primary, while the other neurolymphomas and lymphocytomas were undoubtedly established as a result of metastasis. All of the neurolymphomas in the celiac, sciatic, and brachial nerves of Flock D appeared to be of primary origin and led to the formation of lymphocytomas in the ovary and muscles of the legs and wings by direct infiltration. The malignant growths in other tissues appeared to be of perivascular inception. Figs. 7 and 8 show perivascular infiltration of the sciatic nerves.

In studying these cases it was not always possible to determine whether the nerves or the visceral organs were affected first, although it was demonstrated that metastasis as well as direct infiltration may take place through the nervous system, for the pathological cells appeared to be carried in the capillary spaces. This explains why the connecting link between neurolymphoma and lymphocytoma appeared to be the branches of the larger nerves leading to the visceral organs, and other tissues in which the neoplasms were found. While distant metastasis undoubtedly occurred in some cases, the evidence was not as convincing as in those instances in which direct infiltration or metastasis was traced. Apparently the pathological cell responsible for these malignant growths occasionally develops such invasiveness that any or all tissues are affected. If this deduction is correct, neurolymphomatosis and lymphocytomatosis are closely related and are differentiated on the basis of tissue selection only. Furthermore, this study indicates that neurolymphomatosis is a disease of young birds while lymphocytomatosis is more commonly found in adults ten months or more of age. However, in spite of the conclusiveness of these histological studies, the exact relation between neurolymphomatosis and lymphocytomatosis awaits etiological confirmation, if the theory of an inciting virus is accepted.

The Mortality and Morbidity of Flock C

Next an attempt was made to determine the mortality and morbidity occurring in Flock C from all causes. The results of this study are shown in Table 4.

TABLE 4. A STUDY OF MORTALITY AND MORBIDITY IN FLOCK C

Diseases	Cases	Mortality	Number Recovering	Number not Improved	Average Age When Symptoms Appeared (Days)	Average Age When Death Occurred (Days)	Average Number of Days Sick
Neurolymphomatosis with Gross Lesions	33	30	1	2	79	132	53
Avian Paralysis without Gross Lesions	7	6	0	1	130	168	38
Lymphocytomatosis	11	11	0	0	156	165	9
Neurolymphomatosis and Lymphocytomatosis	5	5	0	0	145	168	23
Myeloleukosis	4	4	0	0	143	146	3
Erythroleukosis	2	2	0	0	92	101	9
Myeloleukosis and Lymphocytomatosis	2	2	0	0	106	120	14
Chronic Coccidiosis	18	2	2	14	145	164	Indefinite
Slipped Tendon	4	0	0	4	44	49	Indefinite
Ascariasis	2	0	0	2	113	163	Indefinite
Visceral Gout	1	1	0	0	167	236	Indefinite
Cannibalism	16	6	10	0	137	139	2

Table 4 shows that avian paralysis with gross lesions, or neurolymphomatosis, led all other diseases in mortality and morbidity. As has been stated before, three birds recovered from neurolymphomatosis, while birds having lymphocytomatosis and leukemia did not recover. In the last two diseases the function of blood-forming organs was seriously interfered with and the birds did not live as long as when affected with neurolymphomatosis. Birds suffering from chronic coccidiosis, slipped tendon, ascariasis, and visceral gout lived indefinitely in a run-down condition. According to the table, the victims of cannibalism lived two days. At the end of this period they were either dead or on the road to recovery. Birds showing complications of neurolymphomatosis and lymphocytomatosis lived 24 days, which is 15 days longer than those showing lesions of uncomplicated lymphocytomatosis.

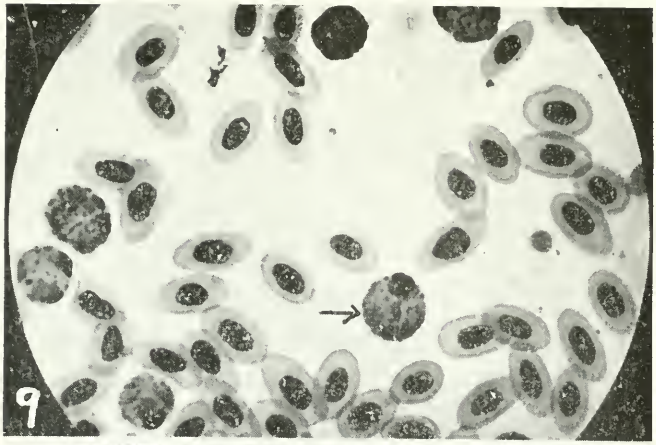
This study indicates that all of these conditions are serious and should be avoided as much as possible.

The Differentiation of Neurolymphomatosis from Lymphocytomatosis and Leukemia

Birds having lymphocytomatosis and leukemia are often unable to stand, and these diseases are mistaken for paralysis or neurolymphomatosis by the laity; but a trained diagnostician should observe that the comb, wattles, face, and mucous membranes in cases of the former are pale, while these parts in the latter are usually of good color. This observation is superficial and should not be depended upon entirely for diagnosis, yet it is of considerable help in the differentiation of neurolymphomatosis from lymphocytomatosis and leukemia in the field. The leukemias are further differentiated in that no immature red cells or immature eosinophilic white cells are found in the circulating blood in either neurolymphomatosis or lymphocytomatosis, and erythroblastic and myeloblastic hyperplasia are found only in the respective leukotic conditions.

The examination of the blood is of the greatest assistance in the differential diagnosis of poultry diseases. Neurolymphomatosis begins with a leukocytosis and ends with a lymphocytosis. Differential counts indicate that the first increase is in eosinophile leukocytes, while the last increase is in small mononuclear lymphocytes. Sometimes the leukocytosis and the lymphocytosis are found overlapping, but generally there is a period between in which the birds apparently hold their own for awhile and the blood count is the same as in normal fowls. In other words, red blood cells, polymorphonuclear leukocytes, neutrophiles, mast cells, and monocytes are the same as in normal birds. In uncomplicated lymphocytomatosis there is a decrease in hemoglobin, the clotting time of the blood is prolonged, and the red blood cells are diminished. Leukocytosis and lymphocytosis occur the same as in neurolymphomatosis. The remaining elements of the blood are seldom disturbed in this disease.

In myeloleukosis the blood is invaded by myelocytes in various stages of development, depending upon the severity of the disease. The pathological cell found in the blood and lesions of the tissues in this disease is the eosinophilic myelocyte, Fig. 9. Neutrophilic and basophilic varieties of this myelocyte may be present in small numbers. Fresh myelocytes usually gave positive oxydase reactions when tested according to the method of Graham (1918) in the early stages of the disease. The liver and spleen were enlarged in advanced cases, and histological sections stained by Mallory's eosin and methylene blue showed more or less myeloblastic hyperplasia. In some advanced cases the bone marrow showed evidence of calcification and the absence of fat. Microscopical examina-



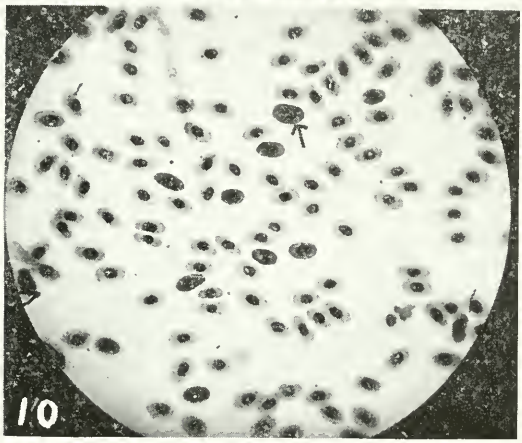


Figure 9. Myeloleukosis. (Magnified 950 diameters.) (Arrow points to myelocyte.)
Figure 10. Erythroleukosis. (Magnified 420 diameters.) (Arrow points to erythroblast.)

tion of the bone marrow showed a diminution, if not an entire absence, of mature leukocytes. The red blood cells were always reduced, the hemoglobin was low, and the clotting of the blood retarded.

Myeloleukosis was differentiated from lympholeukosis on the basis of the pathological cells appearing in the tissues of the birds affected with the respective diseases. In some cases the oxydase test was relied upon to identify the myeloblastic cells of the bone marrow from the cells of the lymphocytic series. A large number of cells with oxydase granules appeared to be characteristic of myeloleukosis just as the reverse seemed to be true of lympholeukosis. In advanced cases of acute myeloblastic leukosis many of the cells may be too immature to react to the oxydase test. This difficulty did not lead to diagnostic error in this study because the blood of the birds was examined at least once as soon as symptoms appeared and at other times later in the course of the disease. But some difficulty was experienced in differentiating generalized infiltration of lymphocytomas from lympholeukosis. Usually lymphocytomas appeared on gross

and histological examination as irregular foci of neoplastic growths embedded in the visceral organs and other tissues, while lympholeukosis appeared to be limited to the liver, spleen, and sometimes the kidney, and always involved the whole of the affected organ.

Blood smears from birds suffering from erythroleukosis showed immature forms of erythrocytes, as shown in Fig. 10. Histological examination of tissues from the liver, spleen, and kidneys revealed intravascular accumulations of these immature cells in the capillary spaces, so that the organs were in a state of distention. Sometimes the distention was so great that hemorrhage occurred. The hemoglobin was reduced in erythroleukosis and the clotting of the blood delayed.

The blood of a representative number of birds for each disease included in this study was examined hematologically. It was impossible to examine all on the experiment because the methods were time consuming, and it was considered better to make a thorough study of a selected number rather than to attempt all of them hurriedly.

The Hematology of Birds from Flock C

The results of the examination of the blood of representative birds from Flock C are contained in Table 5.

The white blood counts recorded for Group 1, were higher than normal in birds Nos. 2, 11, 16, 18, and 19, and lower than normal in No. 1. Differential counts showed that the increase in birds Nos. 11, 16, and 18 was in eosinophilic granular leukocytes, while in bird No. 19 the eosinophilic leukocytes with rods were above normal. Also bird No. 18 showed a high lymphocyte count. The blood of Nos. 3 and 17 was normal, or the same as for healthy birds.

In Group 2, the white cell count was above normal in birds Nos. 13 and 20. Differential counts indicated that the increase in white cells in No. 13 was in polymorphonuclear leukocytes, while that of No. 20 was in small lymphocytes. The blood of Nos. 10 and 14 was normal.

The average white blood cell count was higher in the birds severely affected with paralysis (Group 3) than in Groups 1 and 2. The differential count indicated that this increase was due in general to lymphocytosis, as all of the birds except No. 6 showed relatively high lymphocyte counts. It was found at necropsy that No. 6 had a heavy infestation of roundworms, which may have been responsible for leukocytosis and the probable masking of the lymphocyte count.

The birds in Group 4 were examined hematologically when first brought to the laboratory from the range and again just before death. The symptoms of paralysis had increased in every case. A study of this table shows in most cases a leukocytosis accompanied by a progressive lymphocytosis. The hemoglobin and blood clotting time were not determined in bird No. 33.

The averages of the first and last hematological examinations show some interesting comparisons as follows: The red blood cells are less in the last average count than in the first; the white blood cells are more in the last average count than in the first; the comparison of the first average leukocyte count and the first average lymphocyte count with the corresponding last counts indicates that leukocytosis is giving way to lymphocytosis.

Group 5 contains the results of the hematological studies of birds selected from Flock C that were down and unable to arise, but showed no lesions of paralysis at necropsy. Bird No. 52 gave a low white blood cell count when first examined, but three days later the count was nearly normal. Bird No. 53 showed a marked leukocytosis in which eosinophilic leukocytes with granules predomina-

ted. Bird No. 54 had a high white blood cell count when submitted to the laboratory, but it dropped to nearly normal in five days. Birds Nos. 55, 56, 57, and 58 gave normal blood counts. Gross and histological examination of the nervous systems did not reveal the cause of paralysis in these birds. Possibly they represent cases of leukosis in which hyperplasia is absent, as has been described by Furth (1933).

Group 6 shows the blood counts of birds from Flock C, which showed symptoms of paralysis and anemia during life and at necropsy were found to be affected with neurolymphomatosis and lymphocytomatosis. The eosinophilic granular leucocyte count was high in all of the fowls except No. 62. The significance of this finding, if of any importance, is not understood at present. The hemoglobin was low in all of the birds. The blood clotted rather slowly in fowls Nos. 62, 64, 65, 66, and 67, and the celiac plexus was involved in all of the birds in this group. The ovary was tumorous in three cases, the testicles in one, and the kidneys, liver, and mesenteries in the others. The connection between neurolymphomatosis and lymphocytomatosis of the visceral organs was close in every case. Evidences of metastatic infiltration were found. It may be that when the arteries are filled with lymphoblasts these cells lodge in the capillaries of tissues other than the nervous type, forming foci of infection which lead to the development of the so-called lymphocytoma, which is apparently of the same origin as the neurolymphoma.

The five birds listed in Group 7 had lymphocytomas of the visceral organs, and the nervous system appeared to be normal on gross and histological examination. All of the birds appeared anemic, and had high white blood counts and low hemoglobin determinations. Differential counts showed that all of them had leukocytosis. The blood of Nos. 88 and 89 was counted twice. Bird No. 88 showed no marked changes after 45 days, while the blood of No. 89 indicated a shift from a leukocytosis to a lymphocytosis in 10 days.

Four cases of myeloleukosis were included in the hematological studies and the results are given in Group 8. The red blood cells were low and the white blood cells were higher than normal in all four of these birds. The hemoglobin was very low, the clotting time prolonged, and the birds bled profusely as the blood was drawn from the wing vein for the tests. Differential staining brought out many eosinophilic myelocytes in the blood stream. Also the eosinophilic leukocytes with granules were comparatively increased in bird No. 98. It was observed in this study that the granules in the eosinophilic leukocytes resembled those in the granular myelocytes, but myelocytosis was not always accompanied by a high granular eosinophilic leukocyte count.

Three birds in Flock C were found to have erythroleukosis. These birds were anemic, as shown by the blood counts and hemoglobin determinations in Group 9. The clotting of the blood was much delayed in all three cases. The most characteristic feature of this disease was the presence of erythroblasts and polychrome erythrocytes in the circulating blood. If the blood had not been examined in these cases the diagnosis would have been missed. The liver and spleen were enlarged in all three cases, and histological sections showed that the capillaries of these organs were distended with immature erythrocytes in various stages of development. Erythrocytes were rarely found in the bone marrow of the femur, tibia, radius, and ulna of these birds. The most common cell appeared to be a nucleated, basophilic type, undifferentiated from the large monocyte by Romanosky stains. This cell may have been the precursor of the erythroblasts found in the blood stream.

TABLE 5. HEMATOLOGY OF BIRDS FROM FLOCK C

Bird No.	Age, Days	Days Under Observation	Red Blood Cells	White Blood Cells	Hemoglobin	Blood Clotting Time	Erythroblasts	Polychrome Erythrocytes	Eosinophilic Myelocytes	Eosinophilic Leukocytes: With Rods	Eosinophilic Leukocytes: With Granules	Polymorphonuclear Leukocytes	Neutrophilic and Basophilic Myelocytes	Neutrophilic Leukocytes and Mast Cells	Lymphoblasts	Small Lymphocytes	Large Lymphocytes and Mononuclears
Group 1. Birds Showing Mild Symptoms of Paralysis for Less Than One Week																	
1	30	1	2,830,000	22,000	72.4	1′ 30″	0	0	0	8.0	26.1	4.9	0	0	2.6	1.3	0	36.7	20.4
2	93	5	3,110,000	33,800	74.8	2′ 00″	0	0	0	12.2	15.3	3.0	0	0	3.0	4.1	0	29.7	32.7
3	120	5	2,816,000	25,000	74.4	2′ 45″	0	0	0	16.3	18.7	6.5	0	0	1.1	4.4	0	39.7	13.3
14	102	5	2,732,000	18,000	65.0	4′ 30″	0	0	0	0	45.1	10.0	0	0	0	1.6	0	30.2	13.1
16	83	7	2,872,600	35,900	74.0	2′ 30″	0	0	0	5.0	30.4	6.3	0	0	0	2.4	0	38.7	17.2
17	122	2	3,030,000	26,500	88.3	1′ 30″	0	0	0	14.8	18.0	5.2	0	0	2.0	1.9	0	40.0	18.1
18	125	2	2,798,000	39,000	69.9	2′ 18″	0	0	0	1.0	28.7	5.3	0	0	5.0	2.7	0	19.0	5.3
19	196	1	1,770,000	41,600	71.5	2′ 40″	0	0	0	46.9	5.2	10.4	0	0	0	0	0	1.8	35.7
Average	109	4	2,786,075	33,975	73.8	2′ 28″	0	0	0	13.4	23.4	6.5	0	0	1.7	2.3	0	33.2	19.5
Group 2. Birds Showing Mild or Moderate Symptoms of Paralysis for More Than One Week																	
10	102	12	4,150,000	23,600	78.6	2′ 35″	0	0	0	44.1	26.6	4.4	0	0	2.2	0	0	30.2	22.2
13	112	10	3,210,000	35,400	71.3	2′ 15″	0	0	0	2.7	0	51.3	0	0	0	2.7	0	35.2	8.1
14	122	8	3,450,000	24,400	76.1	3′ 20″	0	0	0	10.0	26.5	12.6	0	0	0	0	0	42.5	8.4
20	244	15	2,900,000	19,000	77.6	2′ 15″	0	0	0	4.8	14.9	1.0	0	0	1.7	1.2	0	65.7	10.7
Average	145	11	3,427,500	33,100	76.7	2′ 36″	0	0	0	8.0	17.0	17.3	0	0	1.0	1.0	0	13.4	12.1
Group 3. Birds Showing Severe Symptoms of Paralysis																	
4	111	5	2,820,000	32,000	72.6	2′ 30″	0	0	0	7.4	31.3	10.4	0	0	1.3	2.3	0	44.1	3.1
5	118	1	2,320,000	10,200	72.0	2′ 40″	0	0	0	3.7	24.9	1.5	0	0	1.0	1.8	0	54.3	12.8
6	121	7	3,260,000	35,000	81.3	1′ 33″	0	0	0	20.3	9.4	30.2	0	0	2.7	1.1	0	30.3	6.0
7	115	1	3,400,000	46,000	80.0	2′ 3″	0	0	0	9.7	14.4	4.3	0	0	2.2	1.4	P*	57.6	10.4
8	84	2	2,600,000	51,000	72.0	3′ 10″	0	0	0	2.8	19.2	0	0	0	0	1.6	P*	52.6	25.2
9	133	17	2,876,000	54,840	73.8	3′ 10″	0	0	0	11.2	12.0	4.4	0	0	2.1	1.4	0	51.5	17.4
12	123	39	200,000	42,400	74.3	1′ 14″	0	0	0	8.6	1.5	18.6	0	0	1.4	1.4	0	54.0	12.8
15	127	13	3,475,000	40,000	78.0	3′ 00″	0	0	0	17.3	19.4	11.1	0	0	0	2.1	0	48.4	2.6
24	257	63	2,490,000	46,000	72.0	3′ 10″	0	0	0	6.4	21.8	3.8	0	0	1.0	1.3	0	54.3	12.4
Average	136	16	2,604,555	43,049	75.1	2′ 33″	0	0	0	9.7	17.1	9.4	0	0	1.3	1.6	P*	49.7	11.4

Group 4. Birds Examined When First Observed and Again Just Before Death

22	85	1	3,200,000	25,000	80.0	1′ 30″	0	0	0	8.0	18.0	2.0	0	0	0	2.0	0	42.0	28.0
	114	29	3,220,000	28,000	80.5	1′ 30″	0	0	0	11.0	28.9	10.3	0	0	1.0	1.6	0	44.1	3.1
23	88	1	3,620,000	23,000	81.4	2′ 15″	0	0	0	11.5	13.0	11.5	0	0	1.0	3.1	0	24.7	5.2
	112	24	3,005,000	32,500	79.5	1′ 30″	0	0	0	5.0	23.0	10.0	0	0	0	2.0	0	42.0	18.0
24	91	1	3,750,000	91,800	75.0	2′ 15″	0	0	0	1.0	40.8	5.4	0	0	0	1.3	0	29.8	21.7
	98	7	3,225,000	84,600	71.5	2′ 25″	0	0	0	0	25.0	8.7	0	0	0	1.3	0	42.8	22.2
25	83	1	3,400,000	25,000	78.2	2′ 15″	0	0	0	9.1	33.1	5.4	0	0	3.1	1.3	0	37.2	10.8
	132	49	3,215,000	31,000	76.8	2′ 30″	0	0	0	10.0	16.0	5.0	0	0	0	2.5	0	48.5	18.0
26	115	1	3,200,000	28,000	75.0	1′ 32″	0	0	0	4.3	29.6	2.5	0	0	0	1.9	0	42.3	19.1
	132	16	3,000,000	30,000	73.9	2′ 21″	0	0	0	4.3	30.0	3.2	0	0	0	2.0	0	40.4	20.1
27	80	1	3,400,000	22,000	78.3	2′ 10″	0	0	0	21.1	38.4	5.7	0	0	2.6	3.2	0	31.1	8.9
	120	1	2,940,000	38,000	76.0	2′ 30″	0	0	0	9.9	19.5	5.4	0	0	1.6	2.0	P*	44.0	17.6
28	105	1	3,100,000	24,000	80.5	1′ 36″	0	0	0	0	32.0	1.8	0	0	1.2	2.2	0	42.8	20.0
	125	20	2,900,000	27,000	71.0	2′ 51″	0	0	0	2.1	25.0	1.5	0	0	.8	2.0	P*	51.6	16.9
29	85	1	2,280,000	35,000	81.6	2′ 15″	0	0	0	10.0	7.0	10.5	0	0	3.5	3.5	0	13.5	22.0
	194	19	2,150,000	39,500	77.9	3′ 18″	0	0	0	2.4	11.8	10.2	0	0	2.9	2.5	P*	56.2	14.0
30	145	1	2,620,000	33,000	80.0	2′ 00″	0	0	0	1.0	17.0	31.5	0	0	0	2.5	0	45.5	2.5
	165	20	2,340,000	43,000	71.7	2′ 52″	0	0	0	2.0	11.5	21.5	0	0	0	2.5	P*	60.0	2.5
31	132	1	2,560,000	22,000	80.0	1′ 30″	0	0	0	6.5	15.1	10.0	0	0	0	2.9	P*	31.4	33.8
	174	12	2,400,000	12,000	73.0	2′ 00″	0	0	0	4.2	10.7	2.0	0	0	2.1	2.9	P*	41.1	36.4
32	82	1	3,100,000	34,000	78.8	3′ 10″	0	0	0	6.0	7.2	28.4	0	0	2.0	4.2	0	13.6	8.6
	112	30	2,900,000	17,000	73.6	2′ 10″	0	0	0	3.1	10.2	5.8	0	0	5.0	3.1	P*	55.8	16.7
33	260	1	4,620,000	26,000	—	—	0	0	0	4.7	20.6	1.1	0	0	1.8	0	0	50.6	21.2
	287	25	1,860,000	21,000	—	—	0	1.3	0	1.0	14.7	4.4	0	0	1.8	2.1	0	41.2	30.5
Averages																			
1st Count	113	1	3,237,500	32,400	79.0	2′ 3″	0	0	0	6.9	25.2	9.7	0	0	1.3	2.3	P*	37.9	16.8
2d Count	117	21	2,762,750	38,633	75.3	2′ 22″	0	0.1	0	4.6	18.8	7.3	0	0	1.3	2.2	P*	47.6	18.0

*P—Present, failed to show oxydase granules.

TABLE 5. HEMATOLOGY OF BIRDS FROM FLOCK C—*Continued*

Bird No.	Age, Days	Days Under Observation	Red Blood Cells	White Blood Cells	Hemoglobin	Blood Clotting Time	Erythroblasts	Polychrome Erythrocytes	Eosinophilic Myelocytes	Eosinophilic Leukocytes: With Rods	Eosinophilic Leukocytes: With Granules	Polymorphonuclear Leukocytes	Neutrophilic and Basophilic Myelocytes	Neutrophilic Leukocytes and Mast Cells	Lymphoblasts	Small Lymphocytes	Large Lymphocytes and Mononuclears
Group 5. Birds Paralyzed and Showing No Lesions of Disease																	
52	184	1	2,660,000	15,090	70.4	2′ 00″	0	0	0	10.0	26.0	18.0	—	0	0	2.2	0	4.5	9.4
	187	3	2,570,000	19,642	68.4	2′ 00″	0	0	0	6.8	22.7	30.0	—	0	1.2	1.5	0	25.1	12.7
53	157	1	2,890,000	93,000	64.6	1′ 30″	0	0	0	24.0	50.0	0	—	0	1.0	3.7	0	18.5	3.7
54	132	1	3,060,000	50,400	40.5	4′ 30″	0	0	0	0	49.0	8.0	—	1.0	2.0	2.0	0	22.0	25.0
	157	5	2,680,000	36,400	67.2	2′ 15″	0	0	0	4.2	29.8	5.0	—	0	0	2.6	0	46.2	21.2
55	77	1	3,031,000	26,490	88.2	1′ 30″	0	0	0	10.0	23.0	5.0	—	0	5.0	2.0	0	47.0	8.0
56	119	1	2,436,000	24,000	77.4	2′ 33″	0	0	0	8.1	36.8	6.7	—	0	0	1.4	0	24.7	22.3
57	96	1	2,870,000	20,100	80.5	3′ 20″	0	0	0	1.1	32.7	1.1	—	0	0	0	0	39.7	25.4
	120	24	2,530,000	22,500	77.9	3′ 20″	0	0	0	0	30.0	5.2	—	0	0	2.8	0	42.0	20.0
58	171	1	2,880,000	14,000	—	—	0	0	0	16.2	39.6	2.8	—	0	0	0	0	10.8	9.6
Average	140	5	2,760,700	32,183	70.6	2′ 33″	0	0	0	11.0	31.3	11.2	—	0.1	0.9	1.8	0	28.0	15.7
Group 6. Birds Showing Lesions of Neurolymphomatosis and Lymphocytomatosis																	
61			2,360,000	20,350	56.2	1′ 20″	0	0	0	19.0	20.5	5.2	—	0	0	1.8	0	44.0	18.5
			1,960,000	12,800	44.2	1′ 20″	0	0	0	0.1	46.1	6.6	—	0	2.0	6.0	0	23.8	15.4
62	137		2,180,000	15,600	52.9	3′ 44″	0	0	0	0	13.9	46.5	—	0	0	0.2	0	34.8	4.6
63	109		2,220,000	14,200	44.2	1′ 20″	0	0	0	7.6	30.0	14.5	—	0	3.0	0.6	0	34.3	10.0
64	177		1,740,000	16,000	40.6	4′ 31″	0	0	0	6.2	34.7	7.6	—	0	2.0	5.2	0	34.6	9.7
65	190		2,105,000	50,000	63.6	6′ 00″	0	0	0	0.2	48.6	2.8	—	0	0	0	0	34.3	14.1
66	96		3,600,000	36,000	64.9	5′ 42″	0	0	0	6.9	40.0	21.1	—	0	1.1	3.3	0	25.0	2.6
67	114		1,392,000	18,700	62.0	4′ 28″	0	0	0	9.0	32.0	14.8	—	0	0	2.1	0	33.7	8.4
Average	137		2,232,125	26,706	53.6	3′ 33″	0	0	0	5.0	33.2	14.9	—	0	1.0	2.4	0	33.1	10.4

Group 7. Birds Showing Lesions of Lymphocytomatosis

88	108	1	2,032,000	27,000	71.0	2′ 6″	0	0	0	0	38.6	18.6	—	0	—	0	—	24.3	18.5
	153	45	1,460,000	28,000	63.0	2′ 10″	0	0	0	0	38.6	18.5	—	0		0.6	—	24.3	18.0
89	157	1	1,861,000	38,160	38.7	2′ 23″	0	0	0	10.0	39.9	9.2	—	0	—	2.6	—	21.3	17.0
	168	11	1,520,000	11,000	25.1	3′ 26″	0	0	0	5.4	18.2	1.8	—	0	—	3.9	—	52.1	15.3
90	205	11	1,550,000	32,000	67.9	1′ 30″	0	0	0	0	78.7	1.3	—	0	—	0	—	20.0	0
91	211	9	1,600,000	44,000	63.0	2′ 00″	0	0	0	0	50.0	5.0	—	0	—	4.5	—	25.0	15.5
92	158	9	2,450,000	28,400	33.1	2′ 15″	0	0	0	1.0	53.3	2.5	—	0	—	3.5	—	9.7	30.0
Average	166	17	1,781,857	35,937	51.7	2′ 16″	0	0	0	2.3	45.3	8.6	—	0	—	2.2	—	25.3	16.3

Group 8. Birds Showing Symptoms and Lesions of Myeloleukosis

97	112	4	1,462,000	36,800	23.6	10′ 35″	0	0	32.1	0	14.0	10.0	—	0	1.8	0	18.1	26.7
98	158	7	1,340,000	11,000	30.0	7′ 30″	0	0	10.0	0	57.2	2.2	—	0	0	0	0	30.6
99	227	1	1,230,000	45,200	25.4	7′ 36″	0	0	43.0	10.0	20.5	2.9	—	0	1.9	0	24.7	0
100	200	5	1,300,000	42,000	24.0	7′ 40″	0	0	45.0	2.0	30.5	3.0	—	0	2.0	2.5	9.0	6.0
Average	174	4	1,333,000	44,250	27.5	8′ 20″	0	0	32.6	3.0	29.8	4.5	—	0	1.4	0.6	13.3	15.8

Group 9. Birds Showing Symptoms and Lesions of Erythroleukosis

101	75	1	1,238,000	41,000	26.6	8′ 30″	2.5	11.4	0	8.4	15.8	1.4	0	0	1.0	2.3	0	42.8	14.4
102	108	1	1,170,000	54,000	26.0	10′ 30″	5.5	42.7	0	0	10.0	10.0	1.2	3.3	4.0	1.0	1.0	38.9	15.4
	198	89	1,345,000	41,000	23.2	11′ 20″	0	24.2	0	1.0	44.5	0	2.0	2.0	1.1	1.4	2.0	45.9	5.6
Average	127	45	1,351,000	45,333	25.3	10′ 7″	2.7	16.1	0	3.1	13.4	3.8	1.1	1.8	1.1	4.6	1.0	42.5	11.8

Coccidiosis

Fifteen uncomplicated cases of coccidiosis were found in Flock C and none in the other flocks. No evidence was found in these studies to indicate that coccidiosis is in any way related to neurolymphomatosis. The hematological studies of the birds affected with coccidiosis are omitted since they add nothing of importance to the investigation.

An Attempt to Differentiate Neurolymphomatosis in Sick Birds from the Range by the Blood Count

The birds in Table 6, Group 1 were sent to the Diagnostic Service from Flock D and it was impossible to hold them under observation for any great length of time. This explains why the leucocytes containing rods and granules were counted together. Also, the neutrophilic leukocytes were not distinguished

TABLE 6. HEMATOLOGY OF BIRDS SHOWING GROSS LESIONS OF NEUROLYMPHOMATOSIS

Bird No	Age, Days	Red Blood Cells	White Blood Cells	Hemoglobin	Blood Clotting Time	Erythroblasts	Polychrome Erythrocytes	Eosinophilic Myelocytes	Eosinophilic Leukocytes (Rods and Granules)	Polymorphonuclear Leukocytes	Neutrophilic and Basophilic Myelocytes	Neutrophilic Leukocytes and Mast Cells	Small Lymphocytes	Large Lymphocytes and Mononuclears	Diagnosis
Group 1. Birds from Flock D															
34	282	3,024,000	25,000	91.1	1′ 30″	0	0	0	25.3	8.6	0	1.8	41.2	23.1	0
35	208	2,250,000	38,400	88.1	1′ 39″	0	0	0	37.2	0.7	0	2.6	37.3	22.2	0
36	245	3,030,000	42,400	92.1	3′ 24″	0	0	0	54.5	1.2	0	0	16.2	18.2	+
37	138	1,960,000	17,400	87.5	2′ 25″	0	0	0	31.6	6.4	0	5.9	46.3	9.8	+
38	138	1,960,000	14,200	74.5	1′ 15″	0	0	0	34.9	10.7	0	12.3	23.7	18.4	0
	232	3,224,000	21,700	88.3	2′ 12″	0	0	0	35.0	12.2	0	0.5	42.3	10.0	0
39	246	3,432,000	24,200	86.3	2′ 6″	0	0	0	27.3	15.0	0	1.5	50.0	6.2	+
40	368	2,242,000	64,000	73.8	2′ 46″	0	0	0	51.2	20.0	0	0	22.4	6.4	+
41	149	3,124,000	29,000	92.6	2′ 15″	0	0	0	30.2	8.4	0	2.4	41.2	14.8	0
42	169	3,390,000	22,600	90.1	1′ 57″	0	0	0	1.9	53.6	0	0	41.5	0	0
43	270	2,250,000	12,800	—	—	0	0	0	29.3	15.9	0	7.1	39.7	17.0	0
Ave.	222	2,715,091	28,336	86.5	2′ 9″	0	0	0	33.8	13.9	0	3.1	36.0	13.3	36.6
Group 2. Birds from Flock E															
44		3,000,000	22,580	72.0	1′ 30″	0	0	0	20.0	11.7	0	1.5	57.3	9.5	+
45		2,210,000	35,200	72.2	2′ 15″	0	0	0	50.0	11.7	0	0.6	37.0	0.7	+
46		3,648,000	24,000	—	—	0	0	0	21.3	7.4	0	2.5	44.3	24.5	0
47		3,240,000	23,800	89.5	1′ 38″	0	0	0	21.9	5.6	0	1.6	55.6	12.3	+
48		3,914,000	23,000	90.1	1′ 24″	0	0	0	25.3	11.7	0	7.7	41.8	13.5	0
49		3,200,000	74,820	79.5	3′ 26″	0	0	0	25.0	9.5	0	0.5	15.0	50.0	+
50		2,390,000	20,400	91.0	2′ 36″	0	0	0	33.1	12.7	0	0.6	36.7	16.0	0
51		3,000,000	41,000	74.5	3′ 29″	0	0	0	24.1	18.2	0	0	47.9	9.8	+
Average		3,075,250	33,100	81.3	2′ 20″	0	0	0	27.6	11.1	0	2.3	42.0	17.0	62.5

from mast cells, and the presence or absence of lymphoblasts in the blood stream was not determined. Aside from these differences the blood was stained and counted the same as for the birds in Flock C. The object of this experiment was to determine whether it is possible to diagnose neurolymphomatosis by roughly counting the blood. The technician counting the blood did not see the birds until the blood had been counted and a report made. Birds Nos. 36 and 40 had high leukocyte counts and were diagnosed correctly by the technician. Birds Nos. 37 and 39 had high lymphocyte counts and were diagnosed as neurolymphomatotic before necropsy. The blood counts of the other six were normal and the diagnosis made by the technician was not confirmed at necropsy. In this experiment the technician relying on blood counts diagnosed only 36.6 per cent of the cases of neurolymphomatosis correctly.

The birds listed in Table 6, Group 2, were in Flock E, which was a mixed group of birds coming from several places in Massachusetts. Birds Nos. 44, 47, 49, and 51 were down and unable to arise. Necropsy revealed extensive nerve infiltration, and blood counts showed marked lymphocytosis. Positive diagnoses were made in these cases from the blood counts. Bird No. 45 showed mild symptoms of disease and an examination of the blood revealed a leukocytosis. This case was diagnosed correctly by the blood count. Birds Nos. 46, 48, and 50 gave normal counts which led to mistaken diagnoses. In this trial 62.5 per cent of the cases of neurolymphomatosis were diagnosed correctly from the blood counts.

The Hematology of Birds from Flocks D and E Affected With Diseases Other Than Uncomplicated Neurolymphomatosis

Two birds in Flock D appeared to be paralyzed, but no lesions of disease were found at necropsy. A study of Table 7, Group 1, shows that both birds gave high lymphocyte counts. The cause of disease in these two birds was not satisfactorily determined. Histological sections of the nervous system did not reveal any evidence of infiltration.

The average age of the birds in Flock D was six months greater than in Flock C and the number of cases of neurolymphomatosis complicated by lymphocytomatosis was doubled. Group 2, shows that all of the red blood counts, except in birds Nos. 71 and 77, were low and the hemoglobin was low in all of the birds. The blood clotting time was prolonged in Nos. 67, 70, 72, 73, 74, 76, 80, 81, and 82. Eosinophilia was noted in Nos. 70, 73, and 78. Lymphocytosis was evident in bird No. 69. This study indicates that there is a definite relation between lymphocytomatosis and anemia.

Four birds in Flock D (Group 3) were affected with lymphocytomas only. The white cell count in all four was high. The differential counts show that the eosinophilic leukocytes were high in Nos. 93, 95, and 96, and the small lymphocytes were above normal in bird No. 94.

Eight cases of myeloleukosis were found in Flock D (Group 4). All of these birds showed relatively low red cell counts and hemoglobin determinations. The blood clotting time was prolonged so that the birds bled easily, and the white cell count was high in all except No. 109. This bird gave a normal white cell count. Eosinophilic myelocytes were present in the blood of all of the birds in varying percentages and the eosinophilic granular leukocytes were above normal. Basophilic myelocytes were identified in the blood of No. 103.

TABLE 7. HEMATOLOGY OF BIRDS FROM FLOCKS D AND E

Bird No.	Age, Days	Red Blood Cells	White Blood Cells	Hemoglobin	Blood Clotting Time	Erythroblasts	Polychrome Erythrocytes	Eosinophilic Myelocytes	Eosinophilic Leukocytes: With Rods	Eosinophilic Leukocytes: With Granules	Polymorphonuclear Leukocytes	Neutrophilic and Basophilic Myelocytes	Neutrophilic Leukocytes and Mast Cells	Small Lymphocytes	Large Lymphocytes and Mononuclears
Group 1. Birds from Flock D, Paralyzed and Showing No Lesions of Disease															
59	207	2,844,000	35,000	81.4	2′ 38″	0	0	0	20.6		3.4	0	1.0	57.7	17.3
60	349	2,708,000	29,640	90.4	1′ 26″	0	0	0	28.2		11.1	0	2.2	46.6	11.9
Average	278	2,776,000	32,320	85.9	2′ 2″	0	0	0	24.4		7.2	0	1.6	52.2	14.6
Group 2. Birds from Flock D, Showing Lesions of Neurolymphomatosis and Lymphocytomatosis															
67	246	2,160,000	19,320	72.1	3′ 27″	0	0	0	37.9		15.4	0	0	43.3	3.4
68	303	2,865,000	29,800	87.4	1′ 46″	0	0	0	31.7		9.8	0	1.1	40.3	17.1
69	145	2,770,000	15,800	69.4	1′ 36″	0	0	0	31.5		1.8	0	0.9	55.7	11.1
70	377	2,662,000	36,000	56.6	4′ 10″	0	0	0	89.3		0	0	0	4.5	6.2
71	350	3,568,000	30,200	87.3	1′ 54″	0	0	0	17.9		31.1	0	3.6	44.1	3.2
72	315	2,940,000	20,400	67.1	4′ 18″	0	0	0	34.9		12.7	0	1.3	33.2	17.9
73	276	1,854,000	35,000	54.2	3′ 20″	0	0	0	47.2		12.2	0	0	25.4	15.2
74	132	2,342,000	35,000	60.2	3′ 14″	0	0	0	31.4		6.8	0	3.0	28.2	30.6
75	123	2,251,000	16,000	50.3	2′ 15″	0	0	0	32.4		18.5	0	1.5	35.3	12.3
76	142	2,986,000	19,000	59.6	3′ 22″	0	0	0	39.8		4.8	0	1.0	40.4	14.0
77	242	3,080,000	5,046	42.3	2′ 33″	0	0	0	39.4		5.2	0	1.0	39.4	15.0
78	246	1,950,000	10,000	60.3	2′ 33″	0	0	0	73.4		0	0	2.0	21.2	3.4
79	271	2,124,000	14,800	50.3	1′ 30″	0	0	0	32.4		18.2	0	0.5	36.8	12.1
80	143	2,100,000	47,000	63.2	3′ 20″	0	0	0	26.2		6.7	0	4.6	40.0	22.5
81	375	1,980,000	44,000	53.0	4′ 49″	0	0	0	23.2		6.3	0	2.9	38.6	29.0
82	385	1,360,000	41,000	33.6	3′ 19″	0	0	0	32.7		8.1	0	1.2	37.0	21.0
Average	254	2,437,188	28,023	60.4	3′ 00″	0	0	0	38.8		9.9	0	1.5	35.2	14.6
Group 3. Birds from Flock D, Showing Lesions of Lymphocytomatosis															
93	393	2,330,000	83,200	41.9	3′ 41″	0	0	0	40.2		10.2	0	3.5	42.6	3.5
94	151	2,810,000	58,000	61.3	3′ 27″	0	0	0	1.0		19.4	0	0	75.3	4.3
95	260	1,849,000	79,200	56.0	2′ 30″	0	0	0	40.4		5.7	0	1.2	46.2	6.5
96	176	1,847,000	70,200	47.5	3′ 10″	0	0	0	46.2		10.4	0	1.1	28.3	14.0
Average	245	2,209,000	72,650	51.7	3′ 13″	0	0	0	32.0		11.4	0	1.5	48.1	7.1

Group 4. Birds from Flock D, Showing Symptoms and Lesions of Myeloleukosis															
103	143	1,162,000	40,000	32.4	12′ 36″	0	0	5.2	0	25.5	10.0	0.7	3.6	42.3	12.7
104	403	1,774,000	60,000	39.3	10′ 26″	0	0	22.4	0	20.6	3.1	0	0.1	47.5	6.0
105	416	1,500,000	53,000	11.8	9′ 30″	0	0	5.8	0	25.3	6.5	0	4.4	41.8	16.2
106	402	1,230,000	45,000	47.3	8′ 42″	0	0	10.2	0	30.2	4.6	0	2.7	37.0	15.3
107	305	1,320,000	62,000	42.4	11′ 30″	0	0	15.8	0	24.2	6.4	0	0.8	47.3	5.5
108	310	1,238,000	80,000	49.3	12′ 31″	0	0	3.7	0	20.6	8.2	0	1.1	52.0	14.4
109	305	2,273,000	27,000	42.4	14′ 37″	0	0	5.0	0	35.0	1.7	0	2.3	40.8	15.2
110	126	2,480,000	42,000	68.4	12′ 37″	0	0	2.4	10.1	37.0	5.2	0	0	37.3	8.0
Average	304	1,622,125	54,125	45.4	11′ 34″	0	0	8.8	1.3	27.3	5.8	0.1	1.9	43.3	11.7
Group 5. Birds from Flock E, Showing Lesions of Neurolymphomatosis and Lymphocytomatosis															
83		1,980,000	25,900	53.2	2′ 46″	0	0	0		28.0	11.1	0	1.3	14.3	15.3
84		1,250,000	42,000	51.0	3′ 20″	0	0	0		2.6	57.1	0	2.3	9.5	28.5
85		1,760,000	40,000	50.4	3′ 00″	0	0	0		31.5	3.4	0	0.9	49.2	15.0
86		2,940,000	90,200	60.9	2′ 30″	0	0	0		36.8	4.4	0	1.4	46.0	11.4
87		1,920,000	41,000	53.6	3′ 32″	0	0	0		30.7	20.6	0	2.1	45.0	1.6
Average		1,961,000	47,820	53.8	2′ 56″	0	0	0		25.9	19.3	0	1.6	38.8	14.4
Group 6. Birds from Flock E, Showing Symptoms and Lesions of Myeloleukosis															
111	299	1,496,000	94,000	47.8	10′ 13″	0	0	8.0	6.0	1.2	6.0	2.8	1.0	68.0	4.0
112	472	996,000	87,000	33.2	4′ 30″	0	0	9.2	2.4	15.2	10.2	4	5.0	41.6	16.4
113	200	1,120,000	60,000	38.6	10′ 50″	0	0	16.5	0	2.6	0.6	1.0	0	31.1	45.3
114	208	1,426,000	67,000	53.1	7′ 32″	0	0	3.8	5.0	15.1	6.4	7.0	2.4	43.8	16.8
Average	220	1,259,500	77,000	43.2	8′ 16″	0	0	9.4	3.4	9.3	5.8	3.5	2.0	46.1	20.6
Group 7. Bird from Flock E, Showing Lesions of Lymphocytomatosis Complicated by Myeloleukosis															
115	300	2,183,000	90,000	45.3	9′ 31″	0	0	15.2	0	8.3	1.5	3.0	3.0	54.6	11.4
Group 8. Bird from Flock E, Showing Lesions of Neurolymphomatosis and Coccidiosis															
116	102	1,769,000	27,000	66.5	3′ 47″	0	0	0	10.0	17.2	5.1	0	3.2	51.6	12.9

All of the birds in Flock E suffering from neurolymphomatosis complicated with lymphocytomatosis, as shown in Table 7, Group 5, had anemia, as indicated by the low red blood counts and hemoglobin determinations. The white blood cells of the birds were high, except in No. 83. The differential counts indicate that bird No. 84 had leukocytosis, while Nos. 85, 86, and 87 had both leukocytosis and lymphocytosis. At necropsy all of the birds showed lesions of neurolymphomatosis and lymphocytomatosis. The neurolymphomas were confined to the sciatic nerves and the lymphocytomas to the adjacent kidney tissues in birds Nos. 83, 85, 86, and 87. In No. 84 general metastasis had apparently taken place, for the left brachial plexus, liver, spleen, intestines, kidneys, proventriculus, lungs, and muscles adjacent to the left brachial plexus were involved in tumor formations. Histological sections indicated that these tumors were all lymphocytomas.

Four cases of myeloleukosis were found in Flock E (Group 6). The most characteristic lesions found in birds Nos. 111 and 112 were chloromas. The neoplasm in No. 111 had apparently originated in the liver and had metastasized to the muscles of the left breast. In bird No. 112 the myelocytoma was generalized and appeared in the liver, spleen, heart, and left thyroid gland. Myeloblasts and myelocytes were found in the blood of all four birds. Fresh myelocytes gave positive oxydase tests. Birds Nos. 113 and 114 did not show characteristic lesions of myeloleukosis on gross examination. But histological examination of tissues from the liver of No. 113 showed myelocytes in the blood of the arteries, sinuses, and capillary spaces. The kidneys were inflamed and swollen, and neoplastic cells were demonstrated in the interstitial tissues surrounding the glomeruli and tubules. The spleen was swollen and the tissues selected from it indicated that a generalized infiltration was taking place in this organ. The mucosa and muscular walls of the intestine were inflamed, but myelocytes were not found in the tissues selected from them. The thyroid glands and vagus nerves were normal to gross inspection, although myelocytes were found in the blood of arteries and capillaries leading into them. One of the thymus glands showed a diffuse infiltration of myelocytes on histological examination. All of the tissues selected from bird No. 114 for microscopical study were normal, except the bone marrow. This was inflamed, devoid of fat, low in eosinophilic leukocytes, and showed evidence of calcification.

One case of lymphocytomatosis complicated by myeloleukosis was found in Flock E, and this was in pullet No. 115. At necropsy lymphocytomas were found involving the liver, spleen, and mesenteries. Reference to Table 7, Group 7, shows that the eosinophilic myelocyte and the small lymphocyte predominated in the blood of this bird.

Only one complication of neurolymphomatosis and coccidiosis was found in this study and that was in Flock E. The hematology of this bird (Table 7, Group 8) shows anemia, eosinophilia, and lymphocytosis as prominent symptoms of this complication.

The Hematology of Healthy Birds

Fifteen healthy birds were examined hematologically for comparison with the results of those in diseased conditions. A study of Table 8 shows considerable fluctuation not only in different birds but in the same bird at different periods. While the examination of the blood is of considerable value in the diagnosis and differentiation of the various forms of leukemia, it is not of much help in the

TABLE 8. HEMATOLOGY OF BIRDS FROM FLOCKS C, D, AND E SHOWING NO SYMPTOMS OR LESIONS OF DISEASE

Bird No.	Age, Days	Days Under Observation	Red Blood Cells	White Blood Cells	Hemoglobin	Blood Clotting Time	Erythroblasts	Polychrome Erythrocytes	Eosinophilic Myelocytes	Eosinophilic Leukocytes: With Rods	Eosinophilic Leukocytes: With Granules	Polymorphonuclear Leukocytes	Neutrophilic and Basophilic Myelocytes	Neutrophilic Leukocytes and Mast Cells	Small Lymphocytes	Large Lymphocytes and Mononuclears
115	126	1	3,820,000	24,600	97.2	1′ 15″	0	0	0	5.0	21.6	15.1	0	5.7	10.2	12.1
	191	65	3,210,000	24,800	93.7	1′ 13″	0	0	0	10.2	25.4	6.6	0	1.2	40.2	13.4
116	192	1	3,980,000	22,800	92.3	1′ 35″	0	0	0	8.1	12.5	19.0	0	7.1	46.2	7.1
	178	76	3,845,000	21,190	89.8	1′ 46″	0	0	0	11.1	21.2	16.4	0	1.5	41.0	5.5
117	133	1	3,197,000	20,682	85.4	2′ 10″	0	0	0	8.7	37.5	10.0	0	3.6	34.4	5.8
	176	43	3,278,000	22,794	91.0	1′ 36″	0	0	0	2.2	31.7	5.0	0	4.2	41.8	12.1
118	123	1	3,700,000	24,000	73.8	1′ 15″	0	0	0	5.7	19.5	7.6	0	5.6	44.8	16.8
	175	52	3,442,000	21,000	71.5	1′ 10″	0	0	0	9.8	21.2	8.0	0	2.6	39.0	16.1
119	130	1	3,100,000	30,000	91.0	2′ 00″	0	0	0	8.0	10.0	12.7	0	4.0	59.6	5.7
120	101	1	2,870,000	27,000	76.3	1′ 30″	0	0	0	4.5	8.3	10.0	0	8.3	46.7	22.2
	135	31	3,100,000	23,400	80.4	2′ 24″	0	0	0	14.5	7.4	6.0	0	3.3	51.6	17.2
121	98	1	2,945,000	24,746	85.4	1′ 38″	0	0	0	0	25.3	2.8	0	2.8	50.7	18.1
122	100	1	2,240,000	24,000	88.4	2′ 00″	0	0	0	5.0	33.4	15.0	0	3.3	40.0	3.3
123	111	1	2,970,000	17,800	87.3	1′ 10″	0	0	0	0.2	30.7	4.6	0	7.2	45.6	11.7
124	158	1	3,050,000	20,000	75.6	1′ 30″	0	0	0	10.0	20.0	15.0	0	5.0	40.0	10.0
125	131	1	3,040,000	19,400	79.5	1′ 30″	0	0	0	0	39.7	15.1	0	5.6	16.9	22.7
126	133	1	2,450,000	31,600	88.2	1′ 30″	0	0	0	3.1	22.5	30.7	0	3.0	27.9	12.8
127	118	1	3,290,000	33,800	77.1	1′ 30″	0	0	0	0.3	46.9	3.3	0	3.3	31.9	14.3
128	198	1	2,930,000	28,800	91.0	1′ 50″	0	0	0	50.0	15.0	1.1	0	1.7	25.0	7.2
129	192	1	2,760,000	17,800	90.4	1′ 40″	0	0	0	48.6	0.4	6.7	0	1.0	42.3	1.0
Average	142	19	3,160,850	24,026	85.3	1′ 47″	0	0	0	10.3	23.0	10.6	0	4.2	40.3	11.8

diagnosis of either neurolymphomatosis or lymphocytomatosis. This investigation indicates that blood counting would not be effective in detecting birds in the early stages of neurolymphomatosis, as suggested by Johnson (1933) and Seagar (1933), because fluctuation in normal birds may temporarily surpass the leukocytosis and lymphocytosis occurring in paralyzed birds. Furthermore, there is usually a period between leukocytosis and lymphocytosis of birds affected with neurolymphomatosis in which there is a tendency for the progress of the disease to be arrested, and the blood picture is often normal during this period. All of these conditions are met in flocks coming down with neurolymphomatosis so that blood counts are unreliable and should not be accepted as a diagnosis, unless accompanied by gross or histological lesions.

During the course of this study the question arose, is there any way of checking the results? A search of the literature did not reveal any way of checking anything except the hematology of healthy birds, and that was not very satisfactory because so many different methods were used that the results are not comparable throughout. Table 9 contains the results of some of the more recent investigations on the hematology of healthy birds.

TABLE 9. THE HEMATOLOGY OF HEALTHY BIRDS AS DETERMINED BY DIFFERENT INVESTIGATORS

	Number of Birds	Red Blood Cells	White Blood Cells	Hemoglobin	Eosinophilic Leukocytes		Polymorphonuclear Leukocytes	Mast Cells	Lymphocytes		Monocytes
					With Rods	With Granules			Small	Large	
Blain, 1928	6		18,630		49.4	8.7		3.6	32.8		5.7
Breusch, 1928		3,468,000	33,300		17.7	4.1		2.5	66.5		9.2
Burnett, 1917		3,300,000	17,921	76.0%	3.3		28.8	4.3	58.0		5.5
Cook and Dearstyne, 1934	78	2,841,000	16,359	10.8 mg	3.1		45.4	5.0	28.7	4.9	14.5
Fernstermacher, 1932	12	2,591,188	24,425	76.0%							
Forkner, 1929	8	3,267,000	24,580	62.9%	34.7	1.8		4.2	41.8		17.1
Klieneberger and Carl, 1912		3,417,000	35,000	62.0%	29.5	4.5		2.2	63.8		0
Present Investigator 1934	20	3,160,850	24,025	85.3%	40.4	23.1	40.5	4.2	40.3	11.8	

A study of Table 9 shows that the same method was used for counting the red and white blood cells by all investigators and the results are comparable. Since hematology has suffered from a lack of a single, simple, accurate method for determining hemoglobin, Pepper and Farley (1933), the results of the various methods in use cannot very well be expected to agree. The present writer used Wong's method and there is no comparative work with birds available. Burnett, Fernstermacher, Forkner, and Klieneberger and Carl used the Newcomer Hemoglobinometer adjusted to read in percentage, and their results are fairly uniform. Cook and Dearstyne determined the hemoglobin colorimetrically with the Newcomer Hemoglobinometer in grams per 100 cc. of blood and there is no other work available for comparison.

Blain, Breusch, Forkner, and Klieneberger and Carl counted the eosinophilic leukocytes with rods and eosinophilic leukocytes with granules separately, but included the polymorphonuclear leukocytes without rods and granules in either one or the other of these groups. Burnett and Cook and Dearstyne recognized polymorphonuclear leukocytes but counted the eosinophilic leukocytes with rods and eosinophilic leukocytes with granules together. Fernstermacher did not include any differential counts. The present writer distinguished the three groups of leukocytes under discussion; but because of variations in counting, the results secured by the different investigators are not comparable.

The mast cell is rather easy to identify in the blood of the healthy fowl, and the variations in counts between the different investigators is probably no more than could be expected between different groups of birds. Therefore, these results are comparable.

Blain, Breusch, Burnett, Forkner, and Klieneberger and Carl did not distinguish small from large lymphocytes as did the more recent investigators, Cook and Dearstyne. The present writer included the monocytes with the large lymphocytes. The results of these investigations on the lymphocytes and monocytes are too variable for comparison.

Since the disagreements by hematologists are almost entirely due to differences in technique, their results do not invalidate the present study in which the same methods were used throughout and the results secured with healthy birds are comparable with those suffering from disease, but they do indicate the need for uniformity in reporting the results of hematological studies for comparison.

Summary and Conclusions

1. The clinical course of neurolymphomatosis varies in individual cases, usually extending over a period of several weeks or months. Complete recovery is rare. Temporary improvement may occur followed by relapse and death.

2. Blood counts indicate that the disease begins with leukocytosis and ends with lymphocytosis. During the period of temporary improvement the blood may be normal.

3. The disease spreads slowly in affected flocks, with only a few birds becoming affected at a time, but new cases continue to develop until it is partially arrested in the late fall.

4. The mortality from neurolymphomatosis is reduced after the first year or two, although it is likely to reappear with each batch of new chickens for an indefinite number of years after it is once established in a flock.

5. Neurolymphomatosis and lymphocytomatosis seem to be closely associated. The former is primarily a disease of young birds from 3 to 10 months of age, while the latter is more common in birds 10 months of age or older.

6. Anemia is a symptom of lymphocytomatosis and leukosis and is not characteristic of neurolymphomatosis.

7. Lympholeukosis is not readily differentiated from lymphocytomatosis.

8. No difficulty was experienced in differentiating neurolymphomatosis from either erythroleukosis or myeloleukosis as the pathological cell is different in all three diseases.

9. The pathological cell appeared to be the same in neurolymphomatosis and lymphocytomatosis, and was characterized by its basic staining properties and the arrangement of the nuclear and chromatin material.

10. This cell was found invading nerves and muscular and visceral tissues by metastatic and direct infiltration. In incipient cases it first appeared in the capillary spaces and destroyed the nerve fibers and interstitial tissues by utilizing the nourishment for the organization of a tumor.

11. Evidence is presented which indicates that incipient lymphocytomatosis and neurolymphomatosis are due to the irritating action of foreign bodies introduced into the peritoneal cavity and tissues. Since bacteria were isolated only from cases in which peritonitis was manifest, the inciting agent is not always bacterial.

12. Attempts to demonstrate the presence of a filtrable virus in neurolymphomatosis and lymphocytomatosis in these experiments failed.

13. Neurolymphomas were most commonly found in the sciatic, vagus, brachial, celiac, optic, and mesenteric nerves; and lymphocytomas were usually located in the ovary, mesentery, kidney, liver, spleen, muscle, and skin.

14. No evidence was found in these studies to indicate that coccidiosis was in any way related to either neurolymphomatosis or lymphocytomatosis.

15. Because of irregularities in the hematology of birds affected with neurolymphomatosis, blood counts were of little assistance in removing diseased birds from affected flocks.

16. On the basis of the experimental data secured in these studies neurolymphomatosis and lymphocytomatosis may be controlled by eradicating affected birds from the flock as soon as noticed, adopting the best sanitary procedures and increasing the vigor of the birds by judicious breeding.

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PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE

3M-6-'34. No. 1501.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 309 May, 1934

Soybeans for Massachusetts

By A. B. Beaumont and R. E. Stitt

To meet the emergencies of shortage in the supply of forage due to crop injury caused by soil or climatic limitations, an interest in certain special annual crops is warranted. This study was undertaken to determine the adaptability of soybeans for that purpose.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

Figure 1. Minsoy, the Best Seed-Producing and Poorest Hay-Producing Variety.

Figure 2. Harbinsoy, an Erect-Growing Variety, on Left and Medium Green, on Right of Stake.

These varieties ranked third and fourth in amount of hay produced. Both are coarse-stemmed varieties and therefore less desirable for hay than Dunfield and Habaro.

SOYBEANS FOR MASSACHUSETTS

By A. B. Beaumont, Professor of Agronomy, and R. E. Stitt[1]

The soybean is a native of southeastern Asia, where for centuries it has occupied a place of outstanding economic importance. The plant was introduced into the United States early in the last century, but did not attract a great deal of attention in this country until about 1890. From that date on the various state agricultural experiment stations have tested many varieties, and have experimented with methods of culture. The Massachusetts Agricultural Experiment Station was actively identified with the early work with this crop through the efforts of Dr. William P. Brooks, who introduced several varieties from Japan, including the well-known Medium Green.

Within the last two decades the acreage of soybeans has increased rapidly in the United States, particularly in the Middle West and the South. The crop has not greatly gained in popularity in the New England states. Owing to climatic restrictions and comparatively small areas of tillable land adapted to extensive use of farm machinery, it is not to be expected that New England may successfully compete with more favorably situated agricultural regions in the production of soybean seed. The greatest promise of the soybean in New England lies in its possibilities as a forage crop. It can hardly compete with the grasses, clovers, and alfalfa as a principal source of forage, but as a more or less temporary or emergency leguminous forage crop it has distinct advantages.

VARIETY TESTS AT MASSACHUSETTS EXPERIMENT STATION

Within the years 1929 to 1932, inclusive, tests of varieties of soybeans were conducted at Amherst by the Massachusetts Agricultural Experiment Station in cooperation with the Division of Forage Crops and Diseases of the Bureau of Plant Industry, U. S. D. A., and the Eastern States Farmers' Exchange. The Division of Forage Crops and Diseases selected the varieties to be tested, supplied the seed, and outlined the general plan of procedure.

The tests for the period 1929-1931, inclusive, were conducted under a uniform technic, the plots consisting of 4 rows 20 feet long and 2.5 feet apart, and being replicated 10 times in the field. In 1932 the plots were changed to 6 rows, 20 feet long and 3 feet apart, and were replicated 5 times. In each case the border rows and a portion of each end of the row were discarded at harvest time to eliminate or reduce border effects. During the earlier period 20 varieties were tested with only one change in the list. In 1932 there was a radical change in the list of tested varieties, those which had previously yielded less than 2.5 tons of cured hay being dropped, and several new introductions added. For these reasons the results of the 3-year test (1929-1931) and the 1932 test are presented separately in this report.

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[1]Formerly Assistant Research Professor of Agronomy. Credit is given to Wm. L. Jones and Jay L. Haddock, holders of the Eastern States Fellowship in Forage Crops, for valuable assistance in the conduct of the tests; and to Dr. E. A. Hollowell and Dr. W. J. Morse of the Bureau of Plant Industry, U. S. D. A., and C. W. Clemmer of the Eastern States Farmers' Exchange for advice in the conduct of the work and writing of the manuscript. Appreciation is expressed also for the financial support given this project by the Bureau of Plant Industry and the Eastern States Farmers' Exchange.

During 1929 and 1930 yields of both hay and seed were obtained for each variety, but owing to comparatively low yields of seed it was decided to omit these records in subsequent years. It was found, as might be expected, that high grain and forage production characteristics of this crop were not combined in a single variety, under the climatic conditions of this section.

Description of Varieties Tested

Black Eyebrow.—Introduced by U. S. D. A. from Wulukai, Manchuria, in 1911. Seeds black with brown saddle and black hilum; about 2475 to the pound; maturing hay in 96 days and seed in 133 days. Used for pasture, hay, and silage.

Chestnut.—Selection in 1907 from the Habaro variety at Arlington Farm, Va. Seeds russet brown with brown hilum; about 3275 to the pound; maturing hay in 88 days and seed in 130 days. Used for hay.

Dunfield.—Introduced by U. S. D. A. from Fanchiatun Station, South Manchuria, in 1913. Seeds straw yellow with light brown hilum; about 3175 to the pound; maturing hay in 96 days and seed in 133 days. Used for hay, pasture, and silage.

George Washington.—A non-shattering selection from the Virginia variety by Harvey S. Clapp, Accotink, Virginia, about 1925. Plants stout, erect, with twining terminals; maturing in about 125 days; pubescence tawny; flowers purple; pods 2-3 seeded; seeds brown with brown hilum; about 3400 to the pound; germ yellow. Especially suitable for hay, silage, and as a soiling crop.

Habaro.—Introduced by U. S. D. A. from Khabarovsk, Siberia, in 1906. Seeds straw yellow with brown hilum; about 3100 to the pound; maturing hay in 96 days and seed in 126 days. Used for hay, seed, and pasture.

Harbinsoy.—Selection at Arlington Farm, Va., in 1921 from an introduction from Penhsiku, South Manchuria. Seeds straw yellow with russet brown hilum; about 2950 to the pound; maturing hay in 111 days; does not mature seed in Massachusetts. Used for hay, pasture, and silage.

Illini.—Pure-line selection from the A. K. variety made by the Illinois Agricultural Experiment Station. Seeds straw yellow with brown hilum; about 2750 to the pound; maturing hay in 105 days and seed in 133 days. Used for hay, pasture, and silage.

Ilsoy.—Pure-line selection from the Ebony variety made by the Illinois Agricultural Experiment Station. Seeds brown with brown hilum; about 3250 to the pound; maturing hay in 111 days; too late for seed maturity in Massachusetts. Used for hay, pasture, and silage.

Ito San.—Introduced from Japan in 1890 by the Kansas Agricultural Experiment Station. Seeds straw yellow with yellow hilum; about 3325 to the pound; maturing hay in 96 days and seed in 130 days. Used for hay, pasture, and silage.

Manchu.—Introduced by U. S. D. A. from Ninguta, Manchuria, in 1911. Seeds straw yellow with both black and brown hila; about 2350 to the pound; maturing hay in 96 days and seed in 133 days. Used for hay, pasture, and silage.

Mandarin.—Introduced by U. S. D. A. from Pehtuanlintza, Manchuria, in 1911. Seeds straw yellow with yellow hilum; about 2910 to the pound; maturing hay in 80 days and seed in 122 days. Used for seed.

Mansoy.—A pure-line selection from Manchu made at Arlington Farm, Va. Seed yellow with slate-black hilum; about 2450 to the pound; maturing hay in 105 days and seed in 135 days. Used for hay, pasture, and silage.

Medium Green.—Introduced from Japan in 1889 by W. P. Brooks, Massachusetts Agricultural Experiment Station. Seeds green with brown hilum; about 2485 to the pound; maturing hay in 111 days and seed in 137 days. Used for hay, pasture, green manure, and silage.

Minsoy.—Developed by Minnesota Agricultural Experiment Station. Seeds straw yellow with brown hilum; about 3700 to the pound; maturing hay in 80 days and seed in 117 days. Used for seed.

Mukden.—Selection from an introduction received from Mukden, Manchuria, in 1920. Named and distributed by the Iowa Agricultural Experiment Station in 1932. Plants stout, erect, bushy, maturing in about 110 days; pubescence gray; flowers white; pods 2-3 seeded; seeds strawyellow with brown hilum; about 2750 to the pound. Valuable as an early grain variety.

Peking.—Selection from Meyer variety at Arlington Farm, Va., in 1907. Seeds black; about 6388 to the pound; maturing hay in 111 days; does not mature seed in Massachusetts. Used for hay and silage.

Pinpu.—Introduced by U. S. D. A. from Harbin, Manchuria, in 1910. Seeds straw yellow with brown hilum; about 2675 to the pound; maturing hay in 96 days and seed in 130 days. Used for hay, grain, and pasture.

Soysota.—Introduced by the Minnesota Agricultural Experiment Station. Seeds brown; about 4900 to the pound; maturing hay in 88 days and seed in 122 days. Used for seed.

Virginia.—Selection from Morse variety at Arlington Farm, Va., in 1907. Seeds brown; about 3455 to the pound; maturing hay in 111 days; does not mature seed in Massachusetts. Used for hay and silage.

Wea.—Introduced by U. S. D. A. from Shuangchengfu, Manchuria, in 1911. Seeds straw yellow with dark olive-brown hilum; about 3246 to the pound; maturing hay in 96 days and seed in 130 days. Used for hay, grain, and silage.

Wilson-Five.—Selection from Wilson variety at Arlington Farm, Va., in 1912. Seeds black; about 5025 to the pound; maturing hay in 111 days; does not mature seed in Massachusetts. Used for hay and silage.

Wisconsin Black.—Developed by Wisconsin Agricultural Experiment Station. Seeds black; about 3085 to the pound; maturing hay in 80 days and seed in 117 days. Used for seed.

Soil, Fertilizer, and Climatic Conditions

These tests were conducted on a soil classified as Agawam fine sandy loam. This is a water-worked soil, of fair to good natural drainage, level to rolling topography, free of stones, and fairly fertile. It is quite homogeneous to a depth of three feet or more, and is sufficiently retentive of moisture to enable crops grown on it to withstand considerable drought. The field was tile-drained. The reaction of the unlimed soil was about pH 5.5, but by liming this was raised to and maintained at about pH 6.0. The texture and structure of the soil are

TABLE 1.— GROWTH CHARACTERISTICS OF SOYBEAN VARIETIES NOTED IN 1929

Variety	Leafiness	Size of Stems	Type of Growth	Height Inches	Days to Maturity		Lodging	
					At Hay Harvest	At Seed Harvest	At time of Hay Harvest	At time of Seed Harvest
Minsoy	Average	Fine	Erect	19	80	117	Non-lodging	Non-lodging
Mandarin	Average	Fine	Erect	..	..	122	Non-lodging	Non-lodging
Wisconsin Black	Average	Fine	Erect	23	80	117	Non-lodging	Non-lodging
Soysota	Leafy	Fine	Erect	23	88	122	Non-lodging	Slightly leaning
Chestnut	Very leafy	Fine	Suberect	28	88	130	Non-lodging	Slightly leaning
Habaro	Average	Fine	Suberect	34	96	126	Non-lodging	Slightly leaning
Ito San	Leafy	Fine	Suberect	35	96	130	Slightly leaning	Slightly leaning
Pinpu	Average	Fine	Suberect	33	96	130	Slightly leaning	Slightly leaning
Wea	Leafy	Fine	Suberect	33	96	130	Slightly leaning	Slightly leaning
Manchu	Average	Coarse	Suberect	41	96	133	Slightly leaning	Partly lodging
Black eyebrow	Few	Coarse	Suberect	39	96	133	Partly lodging	Partly lodging
Dunfield	Average	Fine	Suberect	39	105	134	Slightly leaning	Partly lodging
Illini	Average	Medium	Suberect	47	105	133	Slightly leaning	Partly lodging
Mansoy	Few	Coarse	Suberect	43	105	135	Partly lodging	Nearly lodging
Harbinsoy	Leafy	Very coarse	Suberect	64	111	137	Slightly leaning	Partly lodging
Medium Green	Leafy	Very coarse	Erect	42	111	137	Non-lodging	Slightly leaning
Wilson 5	Few	Very fine	Suberect	52	111	...	Partly lodging	.....
Hsoy	Average	Very fine	Decumbent	57	111	.	Nearly lodging	.....
Peking	Leafy	Fine	Erect	40	111	...	Non-lodging	.....
Virginia	Average	Fine	Decumbent	75	111	..	Nearly lodging	.....

such that good tilth is easily maintained. It can be worked soon after a rain without fear of puddling. Altogether, the soil used may be considered as almost ideal for soybeans.

The soybean plots were rotated on the experimental field. Areas which had received no fertilizer within recent years received 600 pounds of 16 per cent superphosphate and 300 pounds of muriate of potash per acre. This treatment was reduced one-third in amount when the area used for soybeans had been fertilized within recent years for other crops. No nitrogenous fertilizer was used for soybeans. The seed were inoculated with symbiotic bacterial cultures just prior to planting.

There was more or less infestation of downy mildew (*Peronospora sojae* Wolf) and bacterial leaf spot (*Bacterium sojae*) during the period of the test. In 1931 grasshoppers caused some damage, and in 1932 the Mexican bean beetles slightly damaged the crop.

The mean annual rainfall at Amherst is 43.49 inches, and for May, June, July, August, and September 19.53 inches. This is usually fairly evenly distributed throughout the growing season, the mean varying from 3.5 to 4.3 inches per month. The total precipitation for the five months indicated above for the period under consideration was as follows:

Year	Inches
1929	13.09
1930	16.21
1931	24.62
1932	14.75

A severe drought occurred during July and August in 1929, when the total precipitation for these two months was only 2.24 inches. Crops on light, well-drained soils of low water-holding capacity in this vicinity suffered from shortage of water; but owing to the great depth and water-holding capacity of the soil used for this experiment, and probably to a certain amount of water seepage from higher levels, the soybeans did not suffer much, if any.

The mean date of the last frost is May 12, and of the first frost September 19, in Amherst. Thus the mean length of the growing season for tender crops is 130 days. Planting usually occurred about the first of June, and the crop was harvested from about the last week in August to the second week in September. Ample time seems to have been available for production of maximum tonnage of forage of the varieties tested. There is little if any advantage in planting before the first of June, from the standpoint of forage production.

Production Data

In Table 1 are given field notes and data obtained on the varieties tested in 1929. Data such as these will vary more or less from year to year, but they will be of approximately the same relative order.

In Table 2 are given the yield of soybean seed for 1929 and 1930, the only years for which seed yields were taken, and the hay yields for the period 1929-1931, inclusive. A study of this table shows that 1929 was on the whole a better year for seed than 1930, whereas forage production was better in 1930. July of 1929 was abnormally dry and may have permitted better pollination than occurred in 1930 when the rainfall was slightly above normal. The yield of forage may have been conversely affected for the same reason.

TABLE 2.--SUMMARY OF SOYBEAN YIELDS

Variety	Seed, Bushels[1]			Hay[2]							
	1929	1930	Mean	1929		1930		1931		Mean	
				Tons	Rank	Tons	Rank	Tons	Rank	Tons	Rank
Minsoy	25.0	19.0	22.0	1.21	19	1.95	20	2.04	19	1.73	20
Mandarin	....	13.7	....	....	..	2.57	11	1.89	20	2.23	16
Wisconsin Black	20.3	14.2	17.3	1.36	18	2.30	17	2.11	18	1.92	19
Soysota	27.5	15.6	21.6	1.58	17	2.25	19	2.59	9	2.14	18
Chestnut	21.1	11.3	17.7	1.78	16	2.37	16	2.84	2	2.33	15
Habaro	23.6	12.9	18.3	2.55	7	2.91	3	2.80	3	2.75	2
Ito San	20.9	10.9	15.9	2.62	6	2.48	12	2.54	10	2.55	9
Pinpu	20.8	12.0	16.4	2.32	11	2.43	13	2.69	7	2.48	12
Wea	20.8	13.1	17.0	2.17	12	2.58	10	2.54	12	2.43	13
Manchu	19.5	11.4	15.5	2.32	10	3.03	2	2.51	13	2.62	7
Black Eyebrow	16.5	11.9	14.2	2.40	9	2.43	14	2.80	4	2.54	10
Dunfield	17.0	11.1	14.1	2.83	1	3.19	1	3.04	1	3.02	1
Illini	22.0	12.6	17.3	2.78	2	2.59	9	2.54	11	2.64	6
Mansoy	5.9	10.4	13.2	2.01	15	2.83	4	2.68	8	2.50	11
Harbinsoy	4.4	5.5	5.0	2.66	5	2.76	7	2.70	6	2.70	4
Medium Green	7.5	10.2	8.9	2.68	4	2.78	6	2.76	5	2.74	3
Wilson Five[3]	....	....	....	2.11	13	2.41	15	2.50	14	2.34	14
Ilsoy[3]	....	....	....	2.50	8	....	..	....	..	....	..
George Washington[3]	....	....	....	....	..	2.74	8	2.48	16	2.61	8
Peking[3]	....	....	.	2.04	14	2.27	18	2.32	17	2.21	17
Virginia[3]	....	....	....	2.70	3	2.82	5	2.50	15	2.67	5

[1]60 pounds to the bushel.
[2]Yields calculated at 14% moisture.
[3]Did not mature seed.

Yields for 1932 are given in Table 3. Since 6 new varieties were introduced and 11 old ones dropped in 1932, the results can hardly be compared directly with those of 1929-1931. Furthermore, a change in field technic makes direct comparison between results of the two periods difficult.

For the longer period, the five highest-ranking varieties were as follows: (1) Dunfield, (2) Habaro, (3) Medium Green, (4) Harbinsoy, (5) Virginia. The high yields and fine stems of Dunfield and Habaro make them preferable for hay. The coarseness of the stems of Medium Green and Harbinsoy is a point against these varieties for forage. All are suitable for green manure.

TABLE 3.--YIELD OF SOYBEAN HAY IN 1932[1]

Variety	Yield Tons	Rank	Variety	Yield Tons	Rank
Mukden	2.59	1	Mansoy	2.35	9
Wea	2.51	2	F. P. I. 53933-3B	2.33	10
F. P. I. 50536	2.51	3	Illini	2.30	11
F. P. I. 63242-2	2.45	4	F. P. I. 54818	2.29	12
Dunfield	2.14	5	Black Eyebrow	2.23	13
Harbinsoy	2.11	6	Habaro	2.11	14
Manchu	2.13	7	Virginia	2.10	15
F. C. 03654-A	2.39	8			

[1]Calculated at 14% moisture.

UTILIZATION OF SOYBEAN SEED

In the United States soybeans have been used primarily for forage. In recent years increased seed production in the soybean regions has led to new uses with almost unlimited possibilities. Many food and industrial products are being developed from the bean and its by-products, oil and oil meal.

For Livestock.—Soybean seed contain from 30 to 45 percent protein, thus comparing favorably with other concentrated feeds. The growing of seed, therefore, offers the farmer a source of feed at a moderate cost for at least part of the high-protein concentrates needed for stock feeding and milk production.

For Oil and Oil Meal.—The soybean contains a valuable oil which is used extensively in Asia, in Europe, and in North America. At the present time there are more than 20 mills for extracting this oil in the soybean seed production regions of the United States. The oil is used in the manufacture of paints, varnish, soaps, edible oils, butter and lard substitutes, rubber substitutes, linoleum, glycerin, core binder, and numerous other products of which vegetable oils form a part.

The meal or residue remaining after the oil is extracted has proved to be a valuable feed for livestock. In various feeding experiments, soybean meal has compared well with linseed and cottonseed meals as a source of protein for dairy cows, cattle, swine, sheep, and poultry.

For Human Food.—The people of oriental countries have used soybeans as food for many centuries, the protein in their diet being largely supplied from numerous soybean preparations.

The dried beans of light-colored varieties may be cooked and used in the same manner as navy or other beans. Yellow, brown, and green-seeded varieties make a very palatable and nutritious green vegetable when the seeds are three-fourths to full grown. If the pods are boiled for about 5 minutes, the seed can be easily shelled and used in the same manner as green Lima beans or green peas.

Soybean flour, either from the whole bean or from oil meal, is becoming an important food and is a commercial product in many sections of the United States. Extensive tests have shown that this flour can be utilized in various breads and pastries, in the proportion of about one-fourth soybean flour to three-fourths wheat flour. The flour is also used in the manufacture of diabetic foods, breakfast foods, malted milk, crackers, macaroni, and various other foods. Due to the low starch content of the soybean, it is valuable as a basis of foods for diabetic persons and others requiring this type of diet.

THE PLACE OF SOYBEANS IN NEW ENGLAND AGRICULTURE

Generally speaking, the future of the soybean in New England agriculture lies in its ability to produce forage, either as green feed or cured hay. With yields of only 2.5 to 3 tons of cured hay, however, it can hardly be expected to compete with red and alsike clovers and alfalfa, which will yield 3 to 6 tons of cured hay under favorable conditions. Therefore, the main use of soybeans will be as an emergency forage crop to be grown when seedings of clover or alfalfa fail, or when cropping plans need to be changed on short notice, or for special cases. The soybean is perhaps the best emergency leguminous forage for New England.

Hay.—One of the most common uses of the soybean is for hay, which can be fed profitably to all kinds of livestock. As a source of protein that can be produced on the farm to balance feeds for growing stock or for milk and butter production, soybean hay will reduce the quantity of high-priced concentrates that it is necessary to purchase.

According to Henry and Morrison, soybean hay is slightly richer in total digestible nutrients than is alfalfa. Animals usually refuse more of the coarse stems of soybeans than of alfalfa, but this will vary with the variety of soybean and the rate of seeding, a heavy rate giving a finer quality of forage. In Table 4 are given fodder analyses of six varieties of soybeans grown in the test at this Station. In addition the mean analysis of five varieties of alfalfa grown near-by is given for comparison. It will be noted that the soybeans generally run slightly lower in crude protein but higher in nitrogen-free extract and fat than the alfalfa. Considerable variation in the composition of the varieties of soybeans may be noted. It is of interest that the high-yielding varieties in these tests are also high in total digestible nutrients.

TABLE 4.—FODDER ANALYSES OF SOYBEAN AND ALFALFA HAYS[1]

(Dry Matter Basis)

Variety	Protein	Fat	Nitrogen-free Extract	Fiber	Ash
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Habaro	19.50	4.43	41.09	28.01	6.97
Manchu	17.50	2.88	44.00	28.21	7.41
Medium Green	16.34	2.48	41.09	33.79	6.30
Dunfield	15.97	2.76	45.47	29.46	6.34
George Washington	11.51	1.82	39.64	37.15	6.88
Virginia	13.81	2.05	41.45	36.52	6.17
Alfalfa (Mean of 5 Varieties)	18.59	2.61	37.44	33.98	7.38

[1]These analyses, as well as the dry-matter determinations in connection with the variety tests, were made in the Feed Control Laboratory under the direction of Philip H. Smith.

Silage.—The soybean as a supplement to corn silage, using 2 to 3 parts of corn and 1 of soybeans, makes a well-balanced silage that keeps well, is readily eaten by stock, and produces no bad effects on the quality of milk and its products. Soybeans may be grown with the corn, or the crops may be grown separately and mixed in the proper proportions when filling the silo. For silage they may be cut any time from full bloom until the pods are full grown, although the best quality silage is obtained when the seed are one-half to two-thirds grown.

Soiling.—Because of its palatability, ease of handling, and great variation in maturing of varieties, the soybean makes an excellent soiling crop. It is possible to have a green feed throughout the summer and fall by planting varieties of different maturity.

Soil Improvement.—The soybean makes no sod and has but a small root system, and therefore it has but little value for soil improvement unless the entire crop is plowed under. In that respect it is inferior to the clovers and other legumes

of similar growth characteristics. As a green manure or cover crop it should find its widest use on sandy soils subject to wind or water erosion, in orchards, or in any situation where it is necessary to obtain quick growth. For best results as a green manure crop, soybeans should be turned under before the crop becomes mature.

Seed.—For reasons already stated, the growing of soybeans for seed as the main product is not promising for New England. However, under special conditions, such as high prices for seed, this production may be warranted. At present there is considerable popular interest in garden varieties of soybeans suitable for human consumption, and this outlet may be developed in the future.

Figure 3. Soybeans Interplanted with Japanese Millet When Beans Were 6 to 8 Inches High.
Weeds are held in check by this method.

With Other Crops.—Soybeans may be grown to advantage in combination with various crops such as corn, Sudan grass, and sorghums. Corn and soybeans are grown quite extensively, the combination used most commonly for pasturage or silage. Such a mixture reduces the yield of corn, which is only partly compensated for by the yield of soybeans, although the protein of the mixture is increased. The presence of the beans makes hand harvesting very difficult and uneconomical.

The Connecticut (Storrs) Agricultural Experiment Station has made an extensive study of corn and soybean mixtures.[1] It was found that a mixture of

[1]Slate, W. L., Jr., and B. A. Brown. Corn and soybeans as a combination crop for silage. Conn. (Storrs) Agr. Expt. Sta. Bul. 133. 1925.

corn and beans giving one stalk of corn to three of beans per foot of row gave the largest total yield of dry matter and protein. With perfect germination, two-thirds as much soybeans as corn will give this ratio. This is for soybeans of medium size, and due allowance should be made for large or small seeded varieties.

Sudan grass is an excellent crop to grow with soybeans, for not only a higher yield but a better-balanced forage is obtained. The best results are obtained by seeding with a grain drill using about 60 pounds of soybeans and 10 pounds of Sudan grass to the acre.

Millet and soybeans are sometimes used as a forage mixture. Japanese millet may be broadcast at the rate of 10 to 15 pounds per acre between rows of soybeans after the first or second cultivation. The earlier start of the beans prevents their being smothered by the more rapidly growing millet, and the millet is useful in holding weeds in check.

Figure 4. Soybean Root Nodules—the Reason that Three Tons of Hay Can Be Grown on Good Soil Without the Use of Nitrogenous Fertilizer.

HOW TO GROW THE CROP

Soil Requirement.—The soybean is adapted to a wide range of soil types, but may be expected to do best on well-drained sandy loams and sands. Any soil that will grow good corn will grow good soybeans, and the two crops have much the same range in length of growing season. Soybeans have a little wider range and a greater tolerance for unfavorable soil conditions. Though markedly

drought resistant, they will also make a good growth on soil that is too wet for corn. While the soybean is less acid-sensitive than clovers, it responds to lime on acid soils, and fails to thrive in cases of extreme acidity. Soils having a reaction below pH 5.5 should be limed before planting to soybeans.

Preparation of Seed Bed.—A firm seed bed with a layer of fine loose soil at the top will insure the best results. The ground can be plowed either in the fall or in early spring, and disk-harrowed just before planting, to kill all weeds that have started. A firm seed bed can then be obtained with a smoothing harrow.

Fertilizers.—Stable manure can be used to advantage in starting the soybeans, but it should be supplemented with 300 to 400 pounds of superphosphate and 50 to 75 pounds of muriate of potash. A small amount of nitrogenous fertilizer is advantageous in starting the soybeans when manure is not used.

Inoculation.—Soybeans, if well inoculated, gather much of their nitrogen from the air through the nodules on the roots. When seeded for the first time in a field, inoculation is necessary. Commercial soybean cultures can be used, or soil from an inoculated field can be spread at the rate of 250 pounds per acre.

Time and Depth of Seeding.—As soybeans germinate very slowly in cool weather, they should not be planted earlier than corn planting time. They are somewhat more sensitive to frost than is corn. Seedings may be made as late as July 1 in Massachusetts if the soybeans are to be used for hay, soiling, or green manure. Maximum yields will be obtained from seedings made soon after danger from frosts has passed.

In light sandy loams and sands, soybeans may be planted 3 to 4 inches deep. In heavy loams and clays, a depth of about 1 inch gives best results. Differences in emergence due to depth of planting were brought out in a supplementary experiment.[1] From a sandy loam soil plants emerged without difficulty when planted as deep as 4 inches, whereas seedlings had difficulty in emerging from a clay soil when planted as deep as 2 inches. The experiment also showed that seedlings emerged much more rapidly with an air temperature of 72°F. than at 61°.

Method and Rate of Seeding.—Soybeans can be sown in rows wide enough to allow cultivation, or in close drills, or broadcast. Under conditions where weeds are a factor, cultivation may be necessary for weed control. The rows are usually placed 28 inches apart on good soil and from 36 to 42 inches apart on poor soils. The grain drill can be used for sowing either in wide rows or close drills by covering the seed cups to adjust the width of row. Corn planters can be used for planting soybeans by using plates adapted to this purpose. When grown for hay in rows wide enough to allow cultivation, the plants should be spaced about one inch apart in the row. This requires from 20 to 75 pounds of seed per acre, varying with the size of seed and the width of row. If a drill or planter is not available, the seed may be broadcast and covered with a harrow.

Weed Control.—It is not advisable to attempt to grow soybeans in a heavy infestation of witch grass, though it can be done by planting them in wide rows and cultivating them just the same as drilled corn. Nor is it advisable, as a rule, to attempt to grow them in land so wet, heavy, and cloddy that a spike tooth

[1]Reported in a thesis entitled, "A study of varietal and cultural factors affecting the stand and yield of soybeans," submitted by R. E. Stitt to the Faculty of the Graduate School of the Massachusetts State College for the master of science degree, 1930.

harrow or weeder will not work well. On land that can be cultivated with reasonable ease, the ideal procedure is to plow early, harrow at intervals until planting time, plant, smooth and crush clods with a plank drag immediately after planting. The land should then be worked with the weeder or spike tooth harrow, set to work light, often enough to kill the weeds just before the beans come up. Usually three or four harrowings will suffice. In harrowing, the rows may be disregarded for the loss of beans by tramping and pulling will not be serious. Plant at a little heavier rate to take care of the loss. In case it should be found necessary to cultivate the beans for further weed control after they are 5 to 6 inches high, methods and implements ordinarily used for cultivation of corn may be used.

Harvesting Hay.—Soybeans make good hay from the time the pods begin to form until the seeds are about full grown. If the crop is cut when the seeds are one-half to two-thirds developed, a better yield and quality of hay will be obtained. Soybeans are more difficult to cure for hay than other legumes, but may be handled by about the same methods. It is especially important to do the raking while the leaves are somewhat tough, for they will crumble to pieces and be lost if fully dry. If they become too dry to rake without injury, they may be left until towards sunset, when they will regain moisture and may be raked without loss, or they may be raked while dew is still on them the following morning. The hay can be cured even after exposure to rain if it is cocked in such a manner as to allow the free passage of air through it. Curing frames consisting of four upright poles fastened together can be used to advantage. Soybean hay should be thoroughly cured before stacking, housing, or baling.

Harvesting Seed.—Soybeans should not be harvested for seed until the leaves have all fallen and the pods are fully mature. If harvest is too early, the yield of seed will be materially lessened and a poor quality of seed secured. The moisture content will also be high and considerable difficulty experienced in curing the seed properly.

The grain binder may be used to advantage with the taller growing varieties. The bundles should be small and not too tight. If a binder is not available, a self-rake reaper or a mower with a bunching attachment may be used. The ordinary grain thresher can be adapted to threshing soybeans by removing the first concave and substituting a wooden block. The speed of the cylinder should be reduced to about one-half the normal threshing rate.

Combines are now used extensively in the large seed-producing regions. These machines cut the mature plants and elevate them to the cylinder, where the beans are threshed.

Pests of Soybeans

Woodchucks seem to prefer young soybeans to anything else, and if not controlled will destroy an unbelievable acreage in just a few days while the plants are small. The only safe procedure is to patrol the field at least twice a week while the beans are small, looking for bare spots or other evidence of woodchuck damage, and when located, to exterminate the woodchucks forthwith. One or two ounces of calcium cyanide thrown well down the hole, the hole then being sealed with dirt, has proved very effective.

An insect pest that has recently invaded New England is the Mexican bean beetle. While this insect is less injurious to the soybean than to some other bean

varieties, it will do some damage. The pest can be controlled with a poisonous, spray, but this method of control is, of course, impracticable on soybeans to be used for forage.

Soybeans are also subject to certain bacterial, fungous, and virus diseases which in some seasons significantly affect yield and quality of the crop, but which ordinarily are not serious in New England.

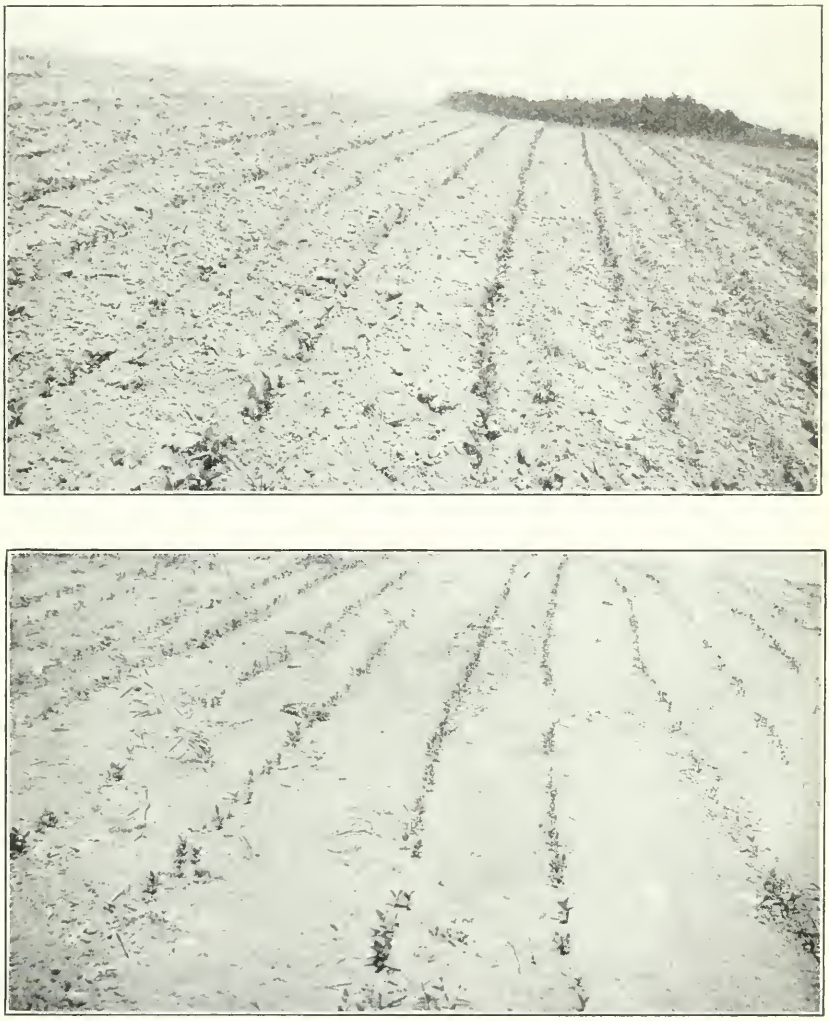

Figure 5. Preparation of Field for Use of a Weeder. (Courtesy J. B. Abbott.)

Upper: Soybeans coming up in a seedbed as left by planter. A harrow or weeder could not be used without serious injury.

Lower: Soybeans coming up in a seedbed finished with a plank drag. On such a seedbed a harrow or weeder can be used at any time necessary to kill weeds without injuring the soybeans.

SUMMARY

Twenty varieties of soybeans were tested for yield of hay for the three-year period 1929-1931. In two of these years yield of seed was also obtained. In the fourth year all varieties which had yielded less than 2.5 tons of cured hay were dropped from the test, and six new introductions added. The principal results and conclusions are as follows:

Generally the forage-producing capacity was found to be in an inverse ratio to the seed-producing capacity of the varieties tested, but there were some exceptions. Seed production varied widely according to the season. Production data of both forage and seed should be accumulated through a longer range of seasons before a definite conclusion can be made on this point.

In the three-year test reported, 11 of 20 varieties averaged 2.5 to 3.02 tons of cured hay. The five highest-yielding varieties were: (1) Dunfield, 3.02 tons; (2) Habaro, 2.75 tons; (3) Medium Green, 2.74 tons; (4) Harbinsoy, 2.70 tons; and (5) Virginia, 2.67 tons. The fine stems of Dunfield and Habaro make them preferable for hay. Medium Green and Harbinsoy have somewhat coarser stems. These four varieties also have an erect or suberect growth, a point in their favor. Virginia is fine-stemmed but decumbent.

An experiment on depth and time of planting showed that these are important factors in the growing of the crop. In light sandy loams or sands, seeds may be planted as deep as 2 inches without reduction of stand. In the heavy loams, about 1 inch is the best depth of planting. Temperature, as governed by time of planting, was found to be important. Seedlings emerged slowly or not at all in cold soils. Seedings may be made from corn-planting time until about July 1.

Due to a comparatively short growing season, general lack of large areas of tillable land suitable to the use of farm machinery, and general economic conditions, the future of the soybean in Massachusetts appears to lie in its capacity to produce high-protein forage rather than seed.

Publication of this Document Approved by Commission on Administration and Finance
4M-5-34. No. 1442

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 310 June, 1934

Supplementary Mid-Morning Feeding of Rural School Children

By Bernice Wait, Oreana Merriam, and Madaline V. Cowing

This study was undertaken to determine whether a mid-morning lunch given to rural school children would produce any measurable effects on their physical or nutritional condition or on their school progress.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

The investigations reported in this bulletin were organized and undertaken by Esther Davies and the work was continued by her until her untimely death on July 12, 1931. During these early stages of the study Dr. Mary S. Rose was very effective as adviser and consultant, and the authors hereby acknowledge their indebtedness.

SUPPLEMENTARY MID-MORNING FEEDING OF RURAL SCHOOL CHILDREN

By Bernice Wait, in charge of Home Economics Research, Oreana Merriam and Madaline V. Cowing, Laboratory Assistants[1]

Supplementary mid-morning school feeding was first used to provide extra food for children who were obviously much underfed. While some children did not seem to respond to such feedings, the results on the whole, as indicated by an initial increase in weight, were sufficiently gratifying so that by 1920 mid-morning milk was quite generally recommended as helpful, if not essential, for correcting undernutrition in school children. In some schools where funds were available the lunch was given not only to the underweights but to all children irrespective of their condition. In this way those who were undernourished were not made conspicuous by being singled out for special treatment, and the large group who were somewhat below par but not sufficiently underweight to be judged "malnourished" also received the benefit of the extra food. It was assumed by those advocating such blanket feeding that the children who were already well-fed would adjust their day's food intake to the extra meal and were in little danger of being overfed, while the majority of children would be benefited.

Palmer (18) reported that a group of Detroit school children who were given a school lunch for eleven weeks in 1919 gained 25 ounces more than their expected gain, while those receiving no lunch lost an ounce. In many unpublished demonstrations similar results were obtained. Because milk is recognized as a most important article in the diet of children, and since so many receive less than the amount generally considered adequate, these mid-morning feedings almost invariably consisted of milk, with or without crackers.

That some other food as well as milk might be effective was suggested by a study made in 1923 at Iowa State College by Newell and Miller (16), who reported a sharp upturn in the weight curves of 12 out of 14 school children when 45 c c of orange juice were given over a three- and later a two-week period. There are, moreover, children who are taking generous quantities of milk and yet are undernourished The question was therefore raised by a few observers whether some other food, such as orange juice, which would supplement milk and was stimulating to the appetite, might be more effective for supplementary feeding in these cases.

With this in mind Chaney (2) observed a group of school children from middle-class homes in Oakland, California, for two 8-week periods. All were 7 per cent or more underweight as judged by the Wood standard but had only minor defects otherwise and were "free to gain" as indicated by medical and dental examinations. Chaney reported (1923) that either fresh orange juice, bottled orangeade, or milk given in the mid-morning seemed of value in overcoming underweight in children, since the mean percentage gains in weight were higher for the fed than for the control groups. Two possible explanations were suggested for the fact that milk produced less-marked gain than orange juice in this test: the lack

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[1]The authors wish to express their appreciation not only to the communities in which the study was carried out, including the children, the parents, the teachers, and the school committees, for their fine cooperation; but also to the dental hygienists and physicians who made the examinations of the children, for their technical assistance; and particularly to Dr. Sallie H. Saunders for her counsel and advice in the evaluation and interpretation of the medical records.

of the antiscorbutic vitamin in milk, and its retarding effect on the appetite. Inquiry indicated that most of the children were taking sufficient milk at home and used oranges less plentifully. For this reason, the orange juice given at school may have supplemented the home diets of these children more effectively than milk.

This investigation was later continued by Morgan and her coworkers (13, 14, 15) in California by observations of small groups of children in the State School for Deaf and Blind and in a junior high school, and a somewhat larger group in a public school where the children came from a lower economic level than those observed by Chaney. As before, the children apparently benefited from the feedings, whether milk, orange juice, figs, or crackers were given. In the first institution, where the basic diet included a quart of milk per child per day but smaller quantities of fresh fruits and vegetables, the best gains were made by the orange-fed groups as Chaney had found. In the last study, in which the children came from poorer homes and had poorer diets, the results were reversed, about equal gains being made by the groups receiving milk or crackers, which in both cases were greater than the gains made by the orange-fed group. In none of these studies was there a significant increase in gain in height. The authors conclude that a definite superiority cannot be assumed for either milk or the fruits for supplementary feeding, and that choice of such lunch for a given group of children should be made only after careful consideration of home diets.

These studies were all made on relatively small groups of underweight children and the results evaluated on the basis of an increased growth for comparatively short periods. In 1928 Orr (17) reported that the addition of approximately a pint of whole or of separated milk to the diet of groups of children of various ages in seven schools in Scotland and Belfast during a 7-month period was accompanied by a rate of growth, both in height and weight, 20 per cent greater than that of groups of children of the same ages, in the same schools, but not receiving the extra milk. The author also observed that there seemed to be an improvement in the general condition of many of the children receiving the milk. This latter finding seems to have been based on general observation rather than on careful comparison of examinations made at the beginning and end of the study.

Since the present investigation was begun, Leighton and Clark (11) (1929) have reported a continuation of the above study confirming Orr's first findings, although the increase in the gain of their subjects in height seemed more marked than their increase in weight. More recently (1931) Laird, Levitan and Wilson (10) have reported that improvement was demonstrated in the behavior of 53 nervous children by giving milk or still more by giving milk plus a calcium–phosphorus–vitamin D concentrate at nine-thirty in the morning. Another study of interest in this connection is that made by Holmes, Pigott, Sawyer and Comstock (8, 9) on a group of underweight women workers in an industrial concern. The authors reported (1930, 1932) that, as a result of giving half a pint of milk and a dessert-spoonful of cod-liver oil six mornings and five afternoons a week from December 1 to May 15, the experimental group was absent less hours per person per month and showed a higher efficiency than the control group.

These studies would indicate that beneficial results may be expected from mid-morning school feedings, at least in many underweight children, and in a large enough proportion to bring about an increased mean gain in weight when given to all the children of a school irrespective of their condition. In actual practice,

however, such lunches have not been found to be always effective even with underweight groups, and in some cases the advisability of the feeding has seemed highly questionable. Instances have also not been infrequent where parents reported the child's appetite to be less at noon following the introduction of the lunch at school, with resulting feeding problems.

Such clinical findings pointed to need of further study of the advantages and disadvantages of school feeding, to ascertain what its possible effects might be not only on the growth of the children but on their general physical and nutritional condition, their school attendance, fatigue, and progress, and the condition of their teeth; whether the beneficial effects were more apparent in children who were in poor condition; and whether some children might fail to improve at all or even show detrimental effects of the lunch. Previous studies made by Davies (4) had indicated that in many homes throughout rural Massachusetts the diets contained limited amounts of milk as well as of fresh fruits and vegetables, at least during the winter months. Under such conditions would a supplementary school feeding of milk or of fresh fruit with a high vitamin C and B content be more efficacious?

It was with such questions in mind that this study was initiated and carried on over a period of four years, involving a fairly large group of children. The findings do not answer all the questions raised but do throw light on some problems as will be indicated in the discussion which follows.

PLAN OF THE INVESTIGATION

Physical Set-Up

This investigation, as has already been suggested, was an attempt to determine to what extent the nutritional status of elementary school children can be improved by supplementary school feeding. Would the results of such feeding be measurable? If positive, would they be sufficient to warrant a community instituting a mid-morning lunch as a part of the regular school routine? Given the usual home diet of rural Massachusetts, is milk or tomato a better food for this purpose? Tomato juice was used because in New England it is less expensive than oranges and at the same time it is a rich source of vitamins, especially of vitamin C.

The project was thus presented to the school committee with the request that the school and community cooperate by allowing the children to be the subjects of the study. The splendid cooperation which was given by these communities is indicated by the fact that with more than 400 families involved, in only nine did the parents raise any objection to their child's part in the project, and in no case was there complete lack of cooperation, even in the control school which was receiving no feeding.

In carrying on the study as well as in presenting the project to the community every effort was made to create a situation such that no conscious changes would be made in the home diets of the children as a result of the school feeding. It is entirely probable that in some cases less milk or tomato may have been used at home because the children were receiving these at school, as may be anticipated in any community when a school feeding is given. There are no data to indicate in which homes this may have occurred. A study of the home diets at the beginning and end of the school year might conceivably have revealed changes that were pertinent to the study. It would have been very difficult, however,

to make the home visits necessary for the collection of such data without at the same time doing some teaching, either consciously or unconsciously, which might influence the diets of the children still more.

Schools Studied

The study was carried on in four consolidated rural schools located in various parts of the State and involved in all some 760 children (386 girls and 374 boys). Of these a fairly large group (230) were observed over a two-year period and 106 for three years. Unfortunately it was not possible to obtain complete records on all these children.

Schools A and B were small, with a total enrollment of approximately 90 children in each. All the grades in these schools were observed. Both were in essentially rural farming communities with only a very small village: the first in a town adjacent to a large metropolitan area, the second in the hills in the western part of the State. The children of school A came largely from old New England or Norwegian stock, those in school B also very largely from old New England families. School C was in a rural industrial village which was in many ways quite different from the other communities. The population was very largely foreign born. More than half the children were of Italian parentage; a large proportion were Lithuanian, Polish, or English; a few were Irish and French; and only a sprinkling were of Yankee stock. School D, which was in a neighboring village in the same town, was, on the other hand, predominantly of native New England stock with a small percentage of French, Irish, Lithuanian, Norwegian, Finnish, and Italian families. The last two schools were much larger, with 40 to 50 children in each grade. Only the lower four grades were used in both, except during the last year when five grades were observed in school D.

Except for the fact that the mills in Village C did not close during 1930–32, even though not running at full capacity, the economic situation in these communities was not unique, but was rather typical of the more prosperous New England rural towns. Probably few of the families would be rated as wealthy though a number were seemingly in quite comfortable circumstances. A large proportion apparently belonged to that economic group with modest means, while not a few had quite meager incomes, and a small group in each community was receiving aid from the town welfare boards.

The Lunch

The study was begun in September 1929 in school A. The children were divided into two groups similar in age and sex. To the one a lunch consisting of a cup of whole milk plus a 20 calorie plain cracker was given; to the other, 1/3 cup of a 50 per cent tomato concentrate, equivalent to approximately 33 calories, plus the same sort of cracker as to the first group. Grade A pasteurized milk with a high fat content (6 per cent[1]) and from a tuberculin-tested Jersey herd was obtained from a neighboring dairy and delivered at school each morning. The tomato concentrate was canned by the Department of Horticultural Manufactures of the State College.[2] The concentrate was thicker in consistency than most commercial products and presumably had a relatively higher food value,

[1]Analysis made by Philip H. Smith of the Experiment Station Control Laboratory.

[2]The tomatoes were first cooked at slow boiling in a covered steam-jacketed kettle for approximately 20 minutes and then pureed. To each gallon of this fine puree 4 1/4 ounces of sugar and 3/4 ounce of salt were added, and the pulp was concentrated to a specific gravity of 1.058, put into No. 2 sized cans and processed in boiling water for 30 minutes.

including its vitamin A content. An assay for vitamin C showed it to be rich in this constituent, 3 c c being sufficient to completely protect a standard guinea pig from scurvy, which was at least equivalent per unit of volume to the original juice.

The work was not continued in School A during the year 1930–31. Further observations as to the value of tomato for mid-morning supplementary feeding were, however, carried on in school B in which all children were given a lunch of ½ cup of tomato puree plus a cracker. This amount proved to be more than the smaller children would take readily. After December 10, 1930, therefore, the amount given the three lower grades was reduced to 1/3 cup.

In the fall of 1930 a two-year study was also started in schools C and D. For these two years (1930–32) the children of the first four grades of the former were given each morning a lunch consisting of a cup of reconstituted evaporated milk plus a cracker, while the children of the same grades of the latter formed the control group and were given no feeding. The milk was reconstituted by adding 5 parts of water to 4 of evaporated milk. Three well-known brands of milk which could be obtained in large containers from local wholesale grocers were used, either mixed or singly. A study of evaporated milk for supplementary school feeding seemed pertinent since many communities do not have a source from which they can obtain milk of a grade safe for school feeding.[1]

Although no detailed analysis of the data of the first two years had been possible at the time, even general observation suggested more or less improvement in the children whether milk or tomato had been given as a supplementary feeding. Since the food values of milk and of tomato are quite different, it seemed possible that a combination of the two might produce a greater improvement than either alone. Accordingly, during the year 1931–32, observations were again made in school A. This year the children were given 2/3 cup of a mixture consisting of 4 parts evaporated milk, 4 parts tomato concentrate, and 1 part water, plus a cracker. Although the tomato was quite acid there was no curdling when it was added to the milk unless the mixture was allowed to stand for an hour or more before serving. When served cold the mixture had a very pleasing flavor and was well liked by the children.

As stated above, the children of school C in the industrial village came largely from foreign homes where the food habits were probably quite different from those of the majority of the children in the other schools including the control school D. Moreover the Italian children, particularly, were noticeably shorter of stature at any given age than the majority of the children in the other school. Because of the inherent differences in the two groups of children the investigation was continued through a fourth year by feeding the control school D. Grades I, II, and IV were given a cup of evaporated milk reconstituted with water; grades III and V, a cup of evaporated milk to which the same proportion of tomato juice had been added. Three well-known commercial brands of tomato juice, all of good quality, were used for this final test. Samples from the shipments given the children were assayed for vitamin C. Two were found to be almost if not quite as rich in this constituent as are canned tomatoes, 3 and 4.5 c c being sufficient to protect a guinea pig from scurvy. The third was less potent, 7 c c failing to give complete protection. Fortunately the second and third brands were fed mixed for the most part, so that the vitamin C content of the milk–tomato mixture as fed, was not greatly different throughout the year.

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[1]This part of the project was financed in part by a grant from the Evaporated Milk Association.

Reaction to the Lunch

The reaction of the children to the evaporated milk was interesting and quite reassuring to any who might hesitate to use this product thinking many children would dislike and refuse it. During the first test the milk was flavored with spice, but this was shown to be unnecessary, for the children in school D took the plain unflavored product as readily as those in school C took the spiced milk. To be sure, a few individuals in each group had difficulty in learning to like the evaporated milk and took the lunch intermittently or only a part of a cup each day, but the same was true when pasteurized milk was given. However, only two in each school, about 1 per cent, refused the evaporated milk entirely because they disliked the flavor.

The way in which the children in all the schools responded to the lunch, whether milk or tomato or a combination of the two, was most gratifying, and is an illustration of the splendid cooperation which may be expected from children if it is requested in such a way as to appeal to their sportsmanship. Much credit for the success in this regard is due to the teachers, whose fine spirit instilled into the children a willingness and a desire to play their part even when their first impulse may have been to refuse and when it took real persistence to bring themselves to like the lunch. Realizing that to many of the children the flavor of evaporated milk would be a new one for which they would have to develop a liking, only about 1/3 cup was given the first day and the amount increased each day until by the end of the second week all were being served a full cup. As was to be expected the greatest lack of cooperation was among the older children, not so much because they really disliked either the milk or tomato as because of their feeling that a mid-morning feeding was only for little children and therefore beneath their dignity. This was particularly obvious in a number of the fifth-grade boys in school D.

The lunch was always given before the first recess in order that it might affect the child's appetite for his next meal as little as possible. In most cases this was at least two hours before the noon meal. The exact time of serving depended on the community and the school program. In school A, for example, most of the children came to school on busses from the surrounding country and were ready for the feeding the first thing in the morning; while in schools C and D, where the majority lived in the village, the lunch was more acceptable somewhat later and was served either during or at the end of the first session.

Throughout each experiment one of the observers (O. M. or M. V. C.) lived in the community where the feeding was being given, to prepare and supervise the lunch. to keep the records of each child's daily intake, and to collect whatever data seemed desirable. In each school, space was provided for this observer to work and for the preparation of the lunch.

Length of Study

With the exception of school B, the supplementary feedings were begun in the last week of September or the first week of October and continued for approximately 150 consecutive school days to the first week of June or for about 8½ months This was exclusive of days in which the school was not in session because of holidays, vacations, or epidemics. In Table 1 the length of the experimental period, the number of children enrolled, and the nature of the mid-morning lunch are given for each school for each year.

TABLE 1.—THE NUMBER OF EXPERIMENTAL DAYS, THE NUMBER OF CHILDREN ENROLLED, AND TYPES OF LUNCH GIVEN IN EACH SCHOOL EACH YEAR

School	Observations Began	Observations Ended	Experimental Days	School Holidays	Children Enrolled			Type of Mid-Morning Feeding
					Boys	Girls	Total	
A	9/25/29	5/29/30	146	28	47	45	92	1 cup pasteurized milk or 1/3 cup tomato concentrate
B	10/27/30	6/ 5/31	136	24	52	39	91	½ or 1/3 cup tomato concentrate
C	10/ 1/30	6/ 2/31	150	25	94	96	190	1 cup evaporated milk
C	9/29/31	6/ 1/32	148	29	88	105	193	1 cup evaporated milk
A	10/ 5/31	5/27/32	149	21	53	48	101	2/3 cup evaporated milk and tomato concentrate
D	10/ 1/30	6/ 2/31	150	25	75	84	159	None
D	9/29/31	6/ 1/32	148	29	78	85	163	None
D	9/26/32	6/ 5/33	150	31	95	92	187	1 cup evaporated milk or 1 cup evaporated milk and tomato juice

Observations Made

In earlier studies the results of supplementary feedings were evaluated, for the most part, on the basis of the child's growth or the rate of gain in weight and height. Such criteria alone are obviously inadequate if a complete picture of the possible effects on the general health and well-being of the subject is to be obtained. It might well be, for example, that a child's nutritional condition would improve even though the rate of his growth was not affected, but this would not be indicated by height or weight alone. Some further measurement of the child's general condition seems highly desirable. In this investigation, therefore, not only were records kept of the child's growth, but each child was given careful medical and dental examinations, his school progress was observed, and his illnesses and absences were noted in order to obtain as comprehensive a picture as possible of any changes which might occur in his condition or his school efficiency during the experimental period. These measurements were all made as near the beginning and end of the experimental period as was possible with the physical set-up in the schools, the number of observers, and the number of children involved. The same observations and records were made of the control as of the experimental groups.

Medical Examinations

The medical examinations were given three times each year: before the feeding was begun in September, in the middle of the year (January), and after the feeding was discontinued in June. These examinations were made with the child stripped to his hips, and records were made using uniform terms throughout in describing the points observed by the physician. (See copy of medical record blank, Table 2.) Tonsils, glands, lungs, heart, and nails were described in detail and at the end of the year evaluated with the help of the examining physician as excellent, good, fair, poor, or very poor.

The services of two competent physicians experienced in children's clinics were secured for this work. The examinations in school B and during the first year in school A were made by one physician; those given during the second year

TABLE 2.—FORM OF MEDICAL RECORDS AND PHRASEOLOGY USED IN DESCRIBING CONDITIONS OBSERVED

Surname First Name Date Birth School Grade

Physical Examination Date

1 POSTURE: erect, slightly round, round, slightly stooped, stooped, or fatigued
2 BODY BUILD: slender, medium, heavy, or very heavy
3 EXPRESSION: alert happy, apathetic, or tired
4 NUTRITION: E, E−, G+, G, G−, F+, F, F−, P+, P, P−, VP+, or VP
5 HAIR: thin or abundant; dry or moist; glossy or lusterless
6 SCALP: clean or dirty
7 EYES: (*); CONJUNCTIVITIS: none, very slight, slight, present, or much
8 NOSE: clear or obstructed; acute coryza or not
9 EARS: infected, injected, or normal
10 LIPS—COLOR: red, slightly pale, pale, very pale, or anemic
11 LIPS—TEXTURE: moist or dry; fissures or not
12 TONGUE: clean or coated
13 MUCOUS MEMBRANE: red, slightly pale, pale, very pale, or anemic
14 BREATH: sweet or fetid
15 THROAT: tonsils described
16 GLANDS—ANTERIOR CERVICAL
POSTERIOR CERVICAL
SUBMAXILLARY
SUBMENTAL
SUBOCCIPITAL
POSTAURICULAR
AXILLARY
INGUINAL
just barely palpable, barely palpable, palpable, or enlarged
If enlarged, diameter indicated
17 CHEST FORMATION: normal or postrachitic EXPANSION: normal or limited
18 LUNGS: resonance—description of abnormal breath sounds and rales
19 HEART: rate, rhythm, strength of beat—any murmurs described
20 ABDOMEN: very firm, firm, slightly soft, or soft; protuberant or not
21 PREPUBESCENT:
22 PUBESCENT:
23 POSTPUBESCENT:
24 SPINE: normal or limited in motion
25 SHOULDERS: straight, round, or stooped
26 SKIN: dry or moist; soft, smooth, or rough; clear or eruptions
27 AMOUNT SUBCUTANEOUS TISSUE: excessive, normal, slightly deficient, deficient, or very much deficient.
28 SKIN COLOR: excellent, good, fair, poor or very poor
29 NERVOUS SYSTEM: normal, hyperactive, or hypoactive
30 NAILS: described as to roughness, softness, brittleness
31 MUSCLE TONE: normal, slightly impaired, impaired, or very much impaired
32 BODILY REPOSE: excellent, good, fair, poor, or very poor

REMARKS: Any colds, or any obervations other than above which seemed pertinent.

*Observations not made after the second year, as there were no measurable changes.

in school A and all in schools C and D were made by the other. It is rather unfortunate that the examinations were not all made by the same doctor, for while the work of each was carefully done and entirely satisfactory, the personal equation is such a large factor that the records of the two are not altogether comparable. The necessity of using great care in choosing a physician for such work was brought out quite strikingly when the records were evaluated. Although both had had much experience in examining children and in well-child clinics before beginning the work of this investigation, each succeeding examination during the first year had obviously been made with greater discrimination, so that the first year has necessarily been treated as a preliminary study. If this were true of physicians who had worked with both well and sick children, how much more should it be expected at first of a general practitioner who has had little professional contact except with sick children.

Dental Examinations

Dental examinations were made twice each year, in September and June, by a well-trained dental hygienist. The general condition of the mouth and gums, the numbers of permanent and deciduous teeth, and the number of pits, fissures and caries were noted. The examinations were made by use of a mirror and a sharp dental explorer or probe, with the child facing a window so that daylight rather than artificial light was used. It did not seem possible under these circumstances to obtain accurate records of the size of the caries or the hardness of the dentine, which might have indicated whether the caries were active or had been arrested during the experimental period. Unfortunately the same hygienist was not able to continue throughout the study so that the personal equation is a possible factor in the variation of results for the first two years. For this reason results are given from the analysis of the data of the last two years only.

Weights and Measures

Insofar as possible the children were weighed and measured at the time of the medical examinations in September, January, and June by one of the workers (O. M. or M. V. C.). Unfortunately this did not seem feasible during the first year (1930–31) in schools C and D, which necessitated the first measurements being made after the feeding was begun and the last before it was ended. As a result, a record of the total gains during that year was not obtained in either school.

All weights were net or nude weights and made with the bladder empty. The child removed all his clothes and donned a weighing robe, or a track suit if he were an older boy, before his weight was taken. As the weight of the robe or suit was known, his net weight was easily calculated. In every instance the weight was taken twice and if the two did not check repeated a third time. Weights were recorded to one ounce. That the variations due to intake of food and drink might be eliminated as far as possible, the January and June weights were made at the same hour of the day as the September one had been, or as near this as could be done.

Heights were measured on a specially constructed stadiometer. The child stood erect on the base platform with his heels, hips, shoulders, and head against a broad board at the back and looking forward with his chin at right angles with his body length. As the scale was double, his height was first read in inches and then in centimeters. If the two readings did not check the height was again

taken. To further assure accuracy the child was asked to relax his position between readings. The measurements were made with the child barefooted.

At the examinations in June and September 1932 and in June 1933 a series of anthropometric measurements were also made, following the technic described by Franzen (7). These included chest depth and breadth, shoulder and hip breadth, calf and forearm girths, and subcutaneous tissue over the biceps and triceps. Only the hip breadth is used in this report.

Achievement Tests

Mental or achievement tests were given in October and in May in all except the first year in school A. During the year 1930–31, the Otis Group Intelligence Scale was used, and the total scores rather than the I. Q.'s compared. The next fall the plan was changed, and achievement instead of intelligence tests were given. Again the total scores rather than the educational or intelligence quotients were compared. The New Stanford Achievement Tests were given to all above the first grade. These are prepared in a series of forms each presumably of equal difficulty. Forms V, W, X, and Y were used in the four succeeding examinations given. That the children might be compared at various mental levels, one intelligence test was also given in the middle of the year. The Haggerty Intelligence Examination was used for the second and third grades, and the National Test for older children. The first grades were given the Pintner–Cunningham Primary Mental Test in the spring and fall. The total scores were used for comparing school progress and a mean of the fall and spring I. Q.'s as indicative of their mental levels. The Otis tests given during 1930–31 were administered by the principal in schools B and C and by the room teachers in school D. All subsequent examinations were administered by one of the writers (B. W.).

Absences and Illness

It is conceivable that a child might be absent from school less because of illness if his nutritional condition were improved. Records were, therefore, kept of the number of days each child was absent during the experimental period together with the reasons, particularly colds and other illnesses. In an attempt to get a more accurate estimate of the prevalence of colds, the number of children in school with colds was noted each day from January first to June first during the last two years. There was no time for a routine examination, but on a chart provided for the purpose the room teacher recorded all cases in which the child had an obvious head cold. As most of the teachers had 40 to 50 youngsters under their supervision, the records can be only superficial, but they are probably indicative of the situation which existed, and it is justifiable to assume that errors are compensatory.

Fatigue

That a mid-morning feeding may be helpful in relieving or decreasing school fatigue has been suggested. It seems now rather unfortunate that no attempt was made to study this point or to get any measurement of the degree of fatigue or of nervousness in the children; particularly so, since the teachers were unanimous in their opinion that the children were more alert, and that discipline problems were less troublesome especially in the hour just before noon, when the feeding had been given earlier in the morning.

Before going on to the problems met in evaluating the data, this discussion

of the mechanics of the study may well be closed by saying that there would have been many squeaking cogs but for the fine spirit with which the whole school and community entered into the project. Much of the success in carrying through the study is due to the cooperation of the teachers in adjusting their programs to the periodic disruptions of their rooms caused by the various examinations and tests and in keeping of records of absences and of colds.

EVALUATION OF THE NUTRITIONAL STATUS OF THE CHILDREN

The Problem

The problem of evaluating the nutritional condition of the children was not the least of the difficulties encountered in the analysis of the data collected in this investigation. The first question to be raised was, What does the phrase, nutritional condition or status, mean? Is it simply a question of the quantity of reserve energy as indicated by the amount of fat padding, whether adequate, insufficient, or excessive? Such a view does not seem reasonable since food supplies not only energy but materials for the building of body tissues and the regulation of body processes. In other words, there is a qualitative as well as a quantitative aspect to the problem, and the nutritional condition of an individual involves the general condition and functioning of his tissues and of his body fluids as well as the amount of fat covering his body. Seham (19) put the matter rather pertinently, though in a negative way, in describing malnutrition in childhood. This condition, he said, is a "a state, a process which manifests itself not only in underweight but in many associated functional disorders. * * *It is not enough to measure the height and weight of the child. Nor is it enough to know about the physical changes that have taken place in the individual."

Weight–Height–Age–Scales

It is now quite generally accepted that neither weight–height nor weight–height–age tables alone are dependable criteria of the nutritional status of children. This, of course, is only common sense if "nutritional condition" is interpreted in its broader meaning. It was apparent, therefore, that the percentage deviation of the child's weight from either Emerson's (6) weight–height scale or the Baldwin–Wood (1) weight–height–age scale could not be used as an index of the nutritional status of our subjects. True, in a large number of cases either standard would probably have given an accurate evaluation, but in many it was obviously incorrect.

For example, the weight of Girl 189 deviated from the average weight for her height and age by but −2.3 or −0.2 per cent, respectively, according to these scales. Even the most casual inspection of the child, however, indicated that she was not in good condition. Though she was fairly well-padded, the subcutaneous tissue was soft and flabby; her color was pale and pasty with huge circles under her eyes; she was listless and apathetic; and her posture was somewhat stooped and fatigued. On the other hand Girl 186 was a tall, rather slenderly built child with all the clinical signs of being in good or even excellent condition. While not plump she had sufficient fat padding so that her ribs were not evident and certainly she would not have been called lean nor "malnourished," as a deviation of 9 and 8 per cent below these standards would indicate. Not a few, particularly boys, might be cited who were rated as seriously underweight by either the Emerson or the Baldwin–Wood scale but who did not appear thin and underweight as they stood stripped and who were in good physical condition

as indicated by the medical examination. It would seem, then, that deviation from the average weight for height is not a dependable criterion of nutritional status even from the quantitative standpoint.

This inadequacy of the weight–height, or weight–height–age tables for measuring the nutritional condition of children is not a new finding but has been pointed out by many previous observers. A number of studies have been reported recently in which attemps were made to work out standards by which the child's condition can be evaluated with greater accuracy.

Skeletal Measurements

The general assumption that weight varies with the body build as well as with stature and with the mass of soft tissues seems logical. Franzen (7) emphasizes the importance of skeletal dimensions in determining weight, and of the size of muscles and the amount of subcutaneous tissue as indicating the nutritional condition of children. He found that the correlation of height with weight was much less than that of other skeletal measures with weight, and pointed out that to base nutrition conclusions on weight–height ratios may cause great errors because of hip and chest variations. He also found that the multiples of eleven factors, including skeletal measures, girths, and amount of subcutaneous tissues, showed a correlation with weight which approached unity. At the time of this writing only the preliminary report of Franzen's study has been published. In this he gives formulae and tables necessary for estimating the relative nutritional status for 11-year-old boys only. Consequently, it has not been possible to use this method in evaluating the nutritional condition of our subjects as had been hoped.

Height–Width Index

Lucas and Pryor in San Francisco (12) have worked out a much simpler standard of "ideal weight" for height and width (hip breadth) at each age. Hip breadth was chosen as the single measure of width to be used because it is easily obtained and is constant. Using the tables compiled by these observers the deviations of actual from "ideal" weight was computed in all cases in which hip breadth had been taken as well as height and weight. To our surprise the values found seemed to be no more trustworthy an indication of the child's condition than those obtained when the Baldwin–Wood scale had been used. Again in a large percentage of cases, perhaps in a majority, the deviation of the child's weight from the expected weight probably gave a quite accurate picture of his nutritional status, but in others it obviously did not. In the instances in which the discrepancy was most evident, the children varied decidedly from the average in some skeletal measurement. For example, some had broad hips but narrow shoulders, or vice versa; others had long slender bones and still had broad shoulders or hips or both; and still others had large heavy bones but were narrow hipped. This is well illustrated by an extreme example. Girl 209 was a very narrow-hipped child but had broad shoulders and fairly large bones. She was quite well padded with fat, although she gave the impression of tending toward thinness rather than fatness. Not by any flight of fancy would one have called her obese although she weighed 28 per cent more than her "ideal" weight.

In a large proportion of cases, particularly when the child was of average build, the expected weight as estimated by the two scales (Baldwin–Wood and Lucas–Pryor) did not differ greatly. When the child was slenderly built, the latter standard seemed to give the more reasonable evaluation.

Medical Examination

The medical examination alone, without taking weight or amount of subcutaneous tissue into consideration, very apparently also gave an inaccurate estimation in numbers of cases, especially of children who were in good general condition but were thin. As Franzen found in his study, there was a tendency for the physician to disregard the lack of subcutaneous tissue in evaluating the condition of such children. For example, Boy 345 who was in excellent general condition was rated as excellent nutritionally even though he was so thin that he appeared to have not one ounce of subcutaneous fat, and though the rating of 23.5 or 19.0 per cent underweight which was indicated by the Baldwin–Wood and the Lucas–Pryor standards seemed to fit the picture he presented. This of course was an exceptional case, but other less striking examples might be cited. On the whole, however, the medical records appeared to give a more reasonable picture than the other standards which it was possible to use with the data available, even though the former were less objective.

Courtis (3) in a recent discussion of "The Prediction of Growth" has said, "Agreement of experience with prediction is the supreme test of scientific truth: That is 'true' which works." Each of the standards available so obviously did not work in so many instances that their dependability as a measure of the nutritional status of the children seemed questionable.

Method of Evaluation Used

In the absence of any reliable standard which would give an objective evaluation of the general condition of the individual child, at the end of the study in each school the senior observer (B. W.) and the assistant who had worked in that school pooled all data which had been collected for each subject and weighed them as carefully as possible. The information used included all the medical records, the evaluation of the child's nutritional condition as made by both the nutritionist and the doctor at the end of each medical examination, the dental records, the child's past history, his absences during the school year, his rate of growth in height and weight together with his deviation from both the Baldwin–Wood and the Lucas–Pryor standards, and a knowledge of the child gained by having worked with him and watched him day after day throughout the school year. From this careful consideration of all information available the general nutritional condition of the child at the time of each medical examination was rated as E, E−, G+, G, G−, F+, F, F−, P+, P, P−, VP+ and VP. In many of the analyses, these ratings have been used simply as excellent, good, fair, poor, and very poor. Two ratings were made in each case, the first an evaluation of the child's condition irrespective of his weight and based largely on the medical records. Reference has already been made to this in discussing the medical examination as an index of nutritional status. The second was an attempt to evaluate the general nutritional status of the subject using all data available and considering both the quantitative and qualitative aspects of the situation.

Such an evaluation was difficult in any case and was very difficult in many instances, especially when the children (as B 345 referred to above) were in good or excellent condition as indicated by the medical records but were nevertheless underweight; or when they had sufficient subcutaneous tissue but their general condition otherwise was only fair or even poor. Just how much importance

should be given to the qualitative evaluation and how much to body weight and the amount of subcutaneous tissue in such cases is a very nice question to decide. Ratings made in this manner, of course, are subjective and severe criticism of their use in analysis of data would be justifiable had they been made by poorly trained or inexperienced observers. Nevertheless, if made by experienced workers who know children as the laboratory man knows experimental animals, who are able to recognize signs of health and well-being on the one hand and of illness and malnutrition on the other, and who have had sufficient experience to enable them to develop standards and power of discrimination, such ratings would seem to be a more accurate index of nutritional status than any obtained by the more objective measures available at the present time. Certainly, incorrect or even absurd evaluations were not apparent, as was true in some cases when any of the conventional methods were used. This should not be interpreted as a contention that the ratings of the general nutritional condition of the children are absolutely accurate. Some variations are inherent because of the personal equation, and the ratings would be expected to differ somewhat if made by another group of workers. They do, however, represent the best combined judgment of two observers on the basis of the data at hand and, the writers feel, give a reasonably accurate basis for interpreting the results of the study. The choice lay between accepting the results from arbitrary methods which have been shown to be inadequate in many instances or from a common-sense evaluation of the best in all methods. The latter seemed the more reasonable procedure. Furthermore, as all the evaluations were made by the same individuals, those for the same child at different seasons and for the various groups should be entirely comparable.

Correlation Between Various Ratings of Nutritional Status

Assuming the more comprehensive general evaluation of the status of our subjects to be the most accurate, it seemed pertinent to make a statistical analysis of the data to determine whether the deductions as to the comparative value of the different methods arrived at by clinical observation were confirmed. For 779 records in which hip breadth was included, the nutritional status of the children was estimated by the use of the Baldwin–Wood and the Lucas–Pryor tables as well as from the medical examinations. These ratings and the amount of subcutaneous tissue, which is the clinical evaluation of the thinness of the child, were all correlated with the ratings of the "general" nutritional condition at the same examination. As had been anticipated the highest correlation was found between the "general" nutritional condition and that obtained from an evaluation of the medical records (qualitative nutritional condition), the coefficient being +.93 (Table 3). This indicates that on the whole these two ratings of nutritional condition do not differ greatly.

The other three correlations did not show so close a relationship and confirm our first observation that none of the quantitative measures of nutrition are dependable guides. A coefficient of even +.72, as was found between the rating for general nutritional condition and the percentage deviation from the Baldwin–Wood standard, does not indicate a close agreement between the results of the two methods for evaluating the same conditions. Somewhat less agreement was shown between general nutritional condition and the amount of subcutaneous tissue ($r = +.64$), and still less with the deviations from the Lucas–Pryor standards ($r = +.49$). It is somewhat surprising that the relationship between this last standard and the general nutritional condition should

have proved to be so low since body width as well as height had been taken into consideration. It is interesting also to note that when these quantitative ratings of nutritional status were correlated with each other or with the qualitative rating no really significant agreement between any two was found (Table 3). The highest were those of the deviation from the Baldwin–Wood standard with the amount of subcutaneous tissue ($r = +.70$) and with the Lucas–Pryor standard ($r = +.66$).

TABLE 3.—CORRELATIONS FOUND BETWEEN THE RATINGS OF NUTRITIONAL STATUS OF CHILDREN. (779 EXAMINATIONS)

Correlation between General Nutritional Condition and	
Qualitative nutritional condition	$+.93 \pm .003$
Amount of subcutaneous tissue	$+.64 \pm .014$
Deviations from the Baldwin–Wood scale	$+.72 \pm .012$
Deviations from the Lucas–Pryor standard	$+.49 \pm .019$
Correlation between Qualitative Nutritional Condition and	
Amount of subcutaneous tissue	$+.53 \pm .012$
Deviations from the Baldwin–Wood scale	$+.58 \pm .016$
Deviations from the Lucas–Pryor standard	$+.35 \pm .022$
Correlation between Amount of Subcutaneous Tissue and	
Deviations from the Baldwin–Wood scale	$+.70 \pm .012$
Deviations from the Lucas–Pryor standard	$+.45 \pm .019$
Correlation between Deviations from the Baldwin–Wood scale and	
Deviations from the Lucas–Pryor standard	$+.66 \pm .014$
Correlation between Evaluation of Nutritionist and	
Evaluation of physician (1559 examinations)	$+.88 \pm .004$

Little correlation was found between the "quantitative" and "qualitative" ratings. Perhaps it is illogical to assume that there should be any correlation and that the nutritional condition of an individual can be judged accurately either by measuring the amount of fat padding or by noting the functioning of his body by a medical examination. Yet investigators have tried to do that very thing. They have looked at the child from either of two very different angles and then wondered why the impressions received were not identical.

In this connection the agreement between the ratings made of the nutritional condition of the child at the end of each examination by the nutritionist and the physician is of interest. These estimates were made independently, the nutritionist recording hers before the physician gave her final evaluation. A fair agreement was indicated for the whole group of 1559 examinations ($r = +.88$). In many instances the estimates were identical, and in a majority the differences were not great. Marked variations occurred for the most part either when the child was in good general condition but thin, when the doctor's rating was higher; or when the child had a severe lung infection though his general appearance was good, in which case the nutritionist's rating was higher.

In such cases, which is the more important from the standpoint of nutrition, thinness or proper functioning of the organs of the body? Are we by chance attempting to treat a situation as if it were a unit when in reality it is dual in nature?

As has been said, just how much weight should be given to the qualitative and how much to the quantitative aspect of nutrition is a nice question to decide. Would it have been wiser not to have attempted to decide it?

TABLE 4.—PERCENTAGE OF CHILDREN* AT EACH LEVEL OF GENERAL NUTRITIONAL CONDITION IN SEPTEMBER, JANUARY AND JUNE

Type of Mid-morning Lunch	School	Year	Month	Total Number of Children	Percentage of Children				
					Excellent	Good	Fair	Poor	Very Poor
Tomato Concentrate	A	1929–30	Sept.	35	6	60	31	3	0
			Jan	34	18	62	17	3	0
			June	35	14	54	32	0	0
	B	1930–31	Sept.	78	9	44	34	13	0
			Jan.	76	16	43	36	5	0
			June	78	17	46	32	5	0
	Total		Sept.	113	8	48	34	10	0
			Jan.	110	16	49	30	5	0
			June	113	16	49	32	3	0
Pasteurized Milk	A	1929–30	Sept.	44	5	39	52	4	0
			Jan.	42	7	55	36	2	0
			June	44	9	57	29	5	0
Evaporated Milk	C	1930–31	Sept.	168	5	57	33	5	0
			Jan.	164	18	54	25	3	0
			June	168	20	56	20	4	0
	C	1931–32	Sept.	164	4	52	34	10	0
			Jan.	160	15	48	28	9	0
			June	164	10	45	26	17	2
	D	1932–33	Sept.	74	4	47	26	20	3
			Jan.	72	20	39	29	11	1
			June	74	19	42	28	10	1
	Total		Sept.	406	4	53	32	10	1
			Jan.	396	17	49	27	7	0
			June	406	16	49	24	10	1
Evaporated Milk and Tomato	A	1931–32	Sept.	69	3	48	38	10	1
			Jan.	69	16	48	32	4	0
			June	69	19	45	29	6	1
	D	1932–33	Sept.	69	7	41	26	19	7
			Jan.	62	13	35	31	19	2
			June	69	12	42	27	16	3
	Total		Sept.	138	5	44	32	15	4
			Jan.	131	15	42	31	11	1
			June	138	15	44	28	11	2
Total Receiving Lunch			Sept.	699	5	50	34	10	1
			Jan.	679	16	48	29	7	0
			June	701	15	49	26	9	1
No Lunch—Controls	D	1930–31	Sept.	102	7	50	35	8	0
			Jan.	97	7	45	41	7	0
			June	102	6	40	45	9	0
	D	1931–32	Sept.	135	12	41	32	14	1
			Jan.	124	11	40	29	18	1
			June	135	13	29	35	21	2
	Other Controls		Sept.	47	11	53	23	13	0
			Jan.	44	23	43	25	9	0
			June	47	26	40	21	13	0
	Total		Sept.	284	10	46	32	11	1
			Jan.	265	12	42	33	13	0
			June	284	13	35	36	15	1

*Records of all children receiving fall examinations used.

ANALYSIS OF DATA AND FINDINGS

Changes in General Nutritional Condition of Children During the Experimental Period

The number of children who were in excellent, good, fair, poor, or very poor general nutritional condition at the time of the fall examination and again in the winter and at the end of the school year have been ascertained for each school, and the percentage at each nutritional level calculated. The results of this analysis are shown in Table 4 and are given in some detail as they indicate the general condition of the various groups of boys and girls at the beginning of the investigation as well as the comparative changes during the experimental period.

Nutritional Status of Children at the Beginning of the Study

The records of 985 children who were examined in the fall and again in the spring were complete enough for the children to be used either as control or as experimental subjects throughout the year. Of this group of almost a thousand children 6 per cent were rated as in excellent condition and 49 per cent as in good general condition, that is, 55 per cent were good healthy youngsters with no serious defects that could be ascribed to nutrition, and a small group were superb specimens; 33 per cent were in only fair condition, being obviously more or less below par in general condition or very thin and much underweight; 11 per cent were judged to be in poor condition and certainly needed attention; while 1 per cent were considered very poor, being in most cases not only very evidently poorly fed but also in need of medical care. Much the same story was found when all controls were compared with the whole experimental group, approximately 55 per cent in each being rated as excellent or good and 45 per cent as fair to very poor at the beginning of the study.

On the whole, the relative numbers of children who were in satisfactory or in unsatisfactory condition were comparable in the various schools. It may be noted, however, that there were more children in poor or in very poor condition and at the same time more superior ones in control school D than in the others, while a relatively large group (55 per cent) in school C were in good condition. The group indicated as "other controls" was made up of older children in school A who had offered to serve as controls, together with all those in any of the groups who had consistently refused to take the feedings. It is interesting that this group of "other controls" contained a smaller proportion of children in fair or poor condition than any others and accounts for the larger percentage of children at these levels of nutrition in the two groups receiving evaporated milk and tomato. It was natural that more pressure was used by both parents and teachers to get children who were obviously in poor condition to take the feeding, and that it was more difficult to persuade children who were well fed to take the lunch if it did not appeal to them. It would appear also that more of the children who seemed least in need of the feeding in school A in the first fall were given tomato and more who were underfed were put in the milk group, probably all unconsciously.

The condition of the boys as compared with the girls varied somewhat from school to school. However, when all were considered, the difference between the two sexes was not great, although slightly more (5 per cent) girls than boys were judged excellent, and fewer fair (Table 5). Perhaps the fact that the boys tended to be leaner with less fat padding may account for this.

TABLE 5.—SUMMARY OF GENERAL NUTRITIONAL CONDITION OF ALL CHILDREN RECEIVING THE FALL EXAMINATION

General Nutritional Condition	Boys		Girls		All Children	
	Number	Per cent	Number	Per cent	Number	Per cent
Excellent	21	4	43	9	64	6
Good	237	49	244	49	481	49
Fair	177	36	147	30	324	33
Poor	51	10	55	11	106	11
Very Poor	3	1	7	1	10	1
Total	489	100	496	100	985	100

Changes in General Nutritional Condition as a Result of Feeding

Some beneficial effect of the school feeding on the general nutritional status of the children is indicated by these data and shown graphically in Chart 1. Whatever the feeding given, the relative number of children in good and excellent condition had increased from September to January, and still more in June in the groups fed milk or a mixture of evaporated milk and tomato, but had decreased in the control group during the same time. Thus at the June examination approximately 65 per cent of the children who had received a mid-morning lunch and 48 per cent of those receiving none were in good or excellent condition, as compared with 55 per cent of both groups in September. As the chart indicates, many of the experimental children who were rated fair or good in the fall were good or excellent in June, with the result that the most obvious change is an increased number in excellent and fewer in fair or poor condition at the end of the year and less change in the numbers in good condition. Among the controls, on the other hand, more were in poor and fewer in good condition in June than in September. The number in excellent condition did not decrease during the year, suggesting that children well fed at home tended to maintain their superior condition throughout the year whether receiving a school feeding or not.

Changes at Different Levels of Nutritional Condition

The slight change in the number of excellent children as compared with good or poor in the control group suggested that children at different nutritional levels might be found to react quite differently to the feeding. Further analysis of the data showed this to be true. The number of children in each group who were in better general nutritional condition at the end of the experimental period than at the beginning was ascertained, as well as those who were in poorer condition and those in whom no change was apparent. The data, figured to a percentage basis, are given in Table 6.

Summary of Changes in the Fed Group

Rating in September	Percentage Better in June	Percentage Showing No Change	Percentage Poorer in June
Excellent	14	58	28
Good	53	29	18
Fair	55	26	19
Poor	63	26	11
Very Poor	75	25	0

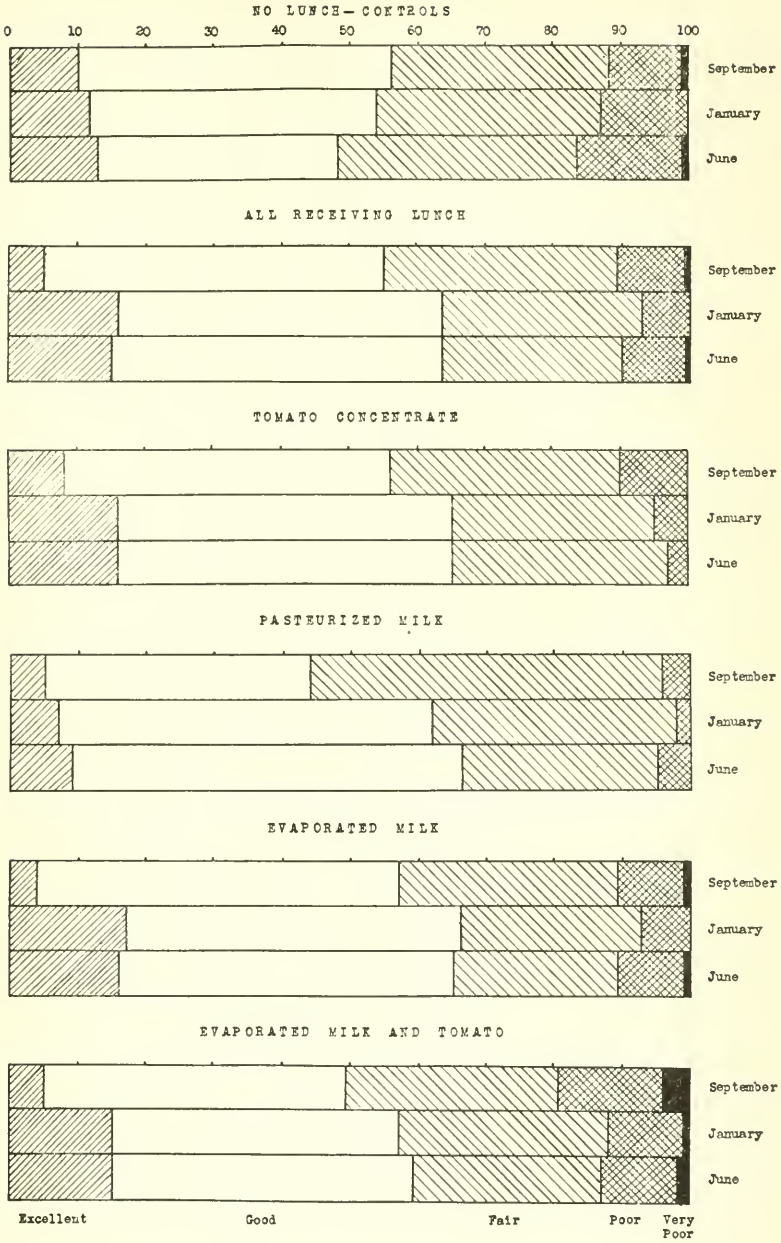

Chart 1. The Percentage of Children in Excellent, Good, Fair, Poor, or Very Poor Nutritional Condition in September, January, and June; showing that the proportion in good and excellent condition increased during the year in the fed groups but decreased in the control group.

TABLE 6.—PERCENTAGE OF CHILDREN* AT EACH NUTRITIONAL LEVEL WHOSE GENERAL CONDITION CHANGED DURING THE PERIOD OF SUPPLEMENTARY SCHOOL FEEDING

Type of Mid-Morning Lunch	General Nutritional Condition in Sept.	September to January				January to June				September to June			
		Total Number of Children	Percentage of Children			Total Number of Children	Percentage of Children			Total Number of Children	Percentage of Children		
			Better in Jan.	Showing no Change	Poorer in Jan		Better in June	Showing no Change	Poorer in June		Better in June	Showing no Change	Poorer in June
Tomato Concentrate	E	9	11	78	11	9	12	44	44	9	11	56	33
	G	53	40	45	15	53	23	49	28	55	36	38	26
	F	39	56	33	11	39	34	51	15	38	61	24	15
	P	10	70	30	0	10	50	40	10	11	73	27	0
	VP	0	..	..	..	0	..	..	..	0	..	..	..
	Total	111	46	42	12	111	28	49	23	113	46	34	20
Pasteurized Milk	E	2	0	50	50	2	0	50	50	2	0	50	50
	G	16	38	24	38	16	31	13	56	17	53	12	35
	F	22	77	14	9	22	41	32	27	23	70	17	13
	P	2	100	0	0	2	0	100	0	2	100	0	0
	VP	0	..	..	..	0	..	..	..	0	..	..	..
	Total	42	60	19	21	42	33	29	38	41	61	16	23
Evaporated Milk	E	19	42	42	16	17	12	24	64	18	17	56	27
	G	226	65	27	8	215	21	49	30	217	58	27	15
	F	133	51	38	11	126	32	43	25	129	50	29	21
	P	38	76	16	8	37	19	22	59	40	50	33	17
	VP	2	50	50	0	2	0	50	50	2	50	50	0
	Total	418	60	31	9	397	24	44	32	406	53	30	18
Evaporated Milk and Tomato	E	8	13	75	13	7	0	86	14	7	14	72	14
	G	60	57	27	16	58	29	45	26	61	48	31	21
	F	50	60	26	14	43	28	44	28	44	59	27	14
	P	23	74	22	4	20	40	20	40	20	80	15	5
	VP	5	80	20	0	5	20	20	60	6	83	17	0
	Total	146	59	28	13	133	29	42	29	138	57	28	15
Total Receiving Milk	E	29	31	52	17	26	8	42	50	27	15	59	26
	G	302	62	27	11	289	24	46	30	295	55	27	18
	F	205	56	32	12	191	32	42	26	196	54	27	19
	P	63	76	18	6	59	25	24	51	62	61	26	13
	VP	7	71	29	0	7	14	29	57	8	75	25	0
	Total	606	60	29	11	572	26	42	32	588	54	28	18
No Lunch—Controls	E	30	3	43	54	29	17	48	35	28	0	39	61
	G	125	34	38	28	126	32	43	25	131	44	25	31
	F	91	19	49	32	91	22	36	42	90	28	22	50
	P	34	35	59	6	33	22	39	39	33	45	21	34
	VP	1	0	100	0	2	50	50	0	2	0	100	0
	Total	281	26	45	29	281	26	41	33	284	34	26	40

*Records of all children receiving fall examinations used.

As suggested above, a very large percentage of the children in excellent condition showed no change during the year. This proportion was greater, however, in the fed than in the control group (58 and 39 per cent respectively). The possible improvement at this nutritional level was, of course, but slight (from a rating of E− to E) and the drop when it occurred was rarely below G+ or G. The percentage of children who showed no change in nutritional status during the year was somewhat less at the other nutritional levels and tended to be least for the children in poor condition. From a glance at the summary it may be seen that the percentage of children who were in poorer condition in June than in September also tended to be less for those who had been rated poor than for those rated good in the fall, while the reverse was true for the children who improved during the year. While the majority of children receiving the lunches showed some improvement during the year, these changes in the individual children were usually not great, more often being only one or two steps as, for example, from G− to G or from G− to G+. These gains or losses on the whole were somewhat less when the child was in good condition than when he was in only fair condition at the start. In other words, the greatest response to the lunch seems to have been made by the children who were in fair or poor condition when the feeding was initiated, as might have been anticipated. That children who were underfed should respond to an increase in their diet after all is not so surprising as that such a large proportion of children who were already in good condition should show improvement. This suggests that, even though not poorly fed, the home diets of the latter group must have been limited in some respects to be so improved by the school feeding.

Comparative Results of Different Types of Lunch

Each type of mid-morning feeding given—whether tomato concentrate, pasteurized milk, evaporated milk, or a mixture of evaporated milk and tomato—produced some improvement in the general nutritional condition of the children as indicated in some detail in Table 6. A summary of these findings shows that a greater proportion of those receiving the lunches than of the controls were in better condition at the end of the year, while fewer of the fed groups were in poorer condition in June.

Type of Mid-Morning Lunch	Percentage Better in June	Percentage Showing No Change	Percentage Poorer in June
Tomato Concentrate.....	46	34	20
Pasteurized Milk.....	61	16	23
Evaporated Milk.....	53	30	18
Evaporated Milk and Tomato	57	28	15
No Lunch—Controls.....	34	26	40

The least improvement occurred in those receiving tomato concentrate, for which several possible explanations may be suggested. In the first place, although richer in vitamin C than milk, tomato does not contain as much of some other food constituents so that its total food value is less. In the second place, 1 cup of milk was fed but only 1/3 to 1/2 cup of tomato concentrate, which was not quite equivalent in food value to 2/3 to 1 cup of the original juice, because of some loss in cooking. And finally, the children's appetites may not have been stimulated sufficiently by the tomato so that their food intake at other meals was increased by as much as a cup of milk, or if stimulated, were not satisfied by foods which had the same beneficial effects as milk.

A slightly greater response to the feeding was observed in those receiving a mixture of evaporated milk and tomato juice than in those receiving the milk alone, but whether the difference is enough to be significant may be questioned. Too great credence should not be placed on the apparent relatively greater improvement shown by the group receiving pasteurized milk, as these figures are based on the preliminary observations and on a relatively small group of children.

Comparison of Changes Occurring in Fall and in Winter

A comparison of the improvement made by the children during the fall with that made during the winter and spring raised the question of possible factors other than the school feeding which may have influenced the condition of the children. It appears that the majority made their gains from September to January and did well to maintain these gains from January to June; while the controls showed no gains in the fall and a larger proportion lost than gained in condition after January. The cause of this difference in response of the children during the fall and the winter, which is constantly in the picture throughout the study, cannot be stated definitely. Probably there was no one cause.

It is conceivable, of course, that in some instances the lunch affected the child's appetite for his noon meal with the result that his total daily food intake was less than when no lunch was given. Under such circumstances the child's condition would have been poorer in June as a result of the feeding itself. The epidemics of colds and acute infections which regularly attack communities during the winter months; smaller quantities of fresh fruits and vegetables in the home diets at this season of the year, and in some instances diets limited because of meager funds at the end of the year; and the lack of summer sunshine are also possible contributing factors. It is also altogether probable that in numbers of cases there were beneficial factors in the child's environment of which we were not cognizant, and that he would have improved during the period of observation without the mid-morning lunch as well as with it. All these factors, both favorable and adverse, which were inherent in the child's environment influenced both the control and experimental children. It would seem for this reason that any differences found consistently in the reaction of the two groups might be attributed, largely at least, to the lunch.

Conclusion

Therefore, the conclusion seems justified that all of the supplementary feedings produced some, though not marked, favorable effects on the general nutritional status of a majority of the children; that milk, either pasteurized or evaporated, was more effective than tomato juice; and that the mixture of evaporated milk and tomato juice apparently gave somewhat better results than either alone.

This conclusion was based on a consideration of the ratings of the general condition of the children which were obtained through an evaluation of all information gathered concerning each child. It is inevitable that in such a general picture some most interesting and illuminating details are lost sight of. An analysis of the data as given by the medical examinations, records of growth in height and weight, absences, illnesses, achievement tests, and dental examinations not only confirms the conclusions drawn from the general nutritional condition of the children but brings out further observations of interest and therefore seems pertinent. A discussion of the findings from each of these phases of the study is given in the pages to follow.

Results of the Feeding as Indicated by the Medical Examinations

Evaluation of Records

The evaluation of the records from the medical examinations presented as many problems and proved as difficult as the estimation of the nutritional status of the children. The reports of other investigators offered little by way of help. Some have attempted to analyze data from medical examinations by tabulating the number of defects found per child, others by determining the relative frequency with which such defects as poor posture, carious teeth, or infected tonsils appeared in the different groups observed. Such analyses did not seem adequate for our purpose, for no improvement would be indicated by these methods unless a given defect was completely corrected, and no possible injury except as a new defect appeared. To illustrate: posture might improve from fatigued to round-shouldered, but round shoulders would still be classed as a defect. To assume that a mid-morning feeding would be a panacea for the correction of the ills of malnutrition and undernutrition seems presumptuous. A more reasonable expectation is that these ills would be either aggravated or improved and occasionally corrected by a supplementary lunch. Our problem was to devise some way of estimating changes in degree of the defects found as well as noting their incidence and disappearance.

One possible method of reaching this objective in part was to ascertain the relative number of children in each group in whom some change for better or for worse occurred in each of the points described in the medical records, as had been done for general nutritional condition; that is, to observe in how many instances the child's posture, or his color, or his tonsils improved or not. Such an analysis has been made and will be discussed later, although it does not give a picture of the changes in the child's physical condition as a whole.

An attempt was made to compile a score card for the evaluation of the medical records which would give such a comprehensive picture. This did not prove feasible, for there were not sufficient data available to indicate how much weight should be given posture, color, tonsils, lungs, subcutaneous tissue, et cetera, in making a complete score card. Whether the conditions found in some of the points observed, as injected conjunctivae, congested lungs, protuberant abdomen, or muscle coordination, are at all influenced by the nutrition of the child or are entirely dependent on other causes, were found to be debatable questions with no data adequate for answering them. A number of experienced pediatricians who were particularly interested in child health from a positive standpoint were approached, but their opinions of the relative importance of various observations in a picture of the whole child were so divergent as to be of no assistance. One man, for example, considered the condition of the lungs in itself to be no indication of the child's nutritional condition; another considered it one of the criteria of minor importance; while a third rated it second to no other and would consider a child with a severe congestion of the lungs, particularly if there were any symptoms suggestive of tuberculosis, to be in poor nutritional condition irrespective of his condition in other respects. All of which is no criticism of pediatricians but simply indicates that our knowledge of what makes up good or poor nutrition and of the extent to which various factors contribute to the whole picture is in a stage which may be quite accurately described as a muddle.

In such a quandary the entirely subjective method which has already been briefly described in the discussion of the estimation of the general nutritional condition of the children was resorted to in evaluating the data given in the

medical records. (See page 15.) That is, at the end of the experimental period the data given in all the records for each child were pooled, weighed, and evaluated by the observers. This seemed the only method possible with the present state of our knowledge, and the authors feel that the ratings derived by its use are a sufficiently accurate index of the condition of the children to be used in analysis of the results of the findings. In a full knowledge of the danger of accusations of being unscientific, this is submitted as the most scientific approach possible to the problem at the present time.

During the first year the details of method and particularly the phraseology for describing the conditions found were being worked into definite form. In each case, also, during the first year the physician so obviously improved in ability to describe the condition of the children with discrimination that the first records are not altogether comparable with those made later. Moreover, the senior author had observed the examinations of the children for only the last two years and as a result had less basis for judging the first two years' records. For these reasons the first two years have been regarded as preliminary, and findings from the analysis of the data reported only when they confirm those of the last two years. In general, however, when any difference was found between the first and last half of the records, it was in degree and constancy rather than in trend of results.

Relationship of Points Observed to "Qualitative" Nutritional Condition

Since so little information was available that indicated to what degree a clinical sign may be an index of nutrition, it seemed of interest to determine what relationship existed between the various points observed by the physician and the nutritional status of the children as judged from the medical examination. Accordingly, correlations were run for all the observations in which the description had been sufficiently detailed to make the comparison of statistical value. Only the examinations made during the last two years were used. The coefficients of correlation obtained are given in Table 7.

TABLE 7.—THE CORRELATION OF THE VARIOUS POINTS OBSERVED BY THE PHYSICIAN WITH THE NUTRITIONAL CONDITION OF THE CHILDREN AS JUDGED FROM THE MEDICAL EXAMINATION

Points observed	Number of Examinations	Coefficient of Correlation
Muscle tone	1808	$+.70 \pm .008$
Skin color	860	$+.69 \pm .011$
Lungs	1807	$+.55 \pm .011$
Amount of subcutaneous tissue	1803	$+.53 \pm .012$
Posture	1804	$+.50 \pm .012$
Glands (total scores)	1807	$+.41 \pm .013$
Tonsils	1297	$+.38 \pm .016$
Color of mucous lining of mouth	1296	$+.30 \pm .016$
Bodily repose	1804	$+.27 \pm .015$
Heart	1807	$+.19 \pm .015$
Color of lips	1806	$+.17 \pm .015$
Conjunctivae (injection)	1807	$+.07 \pm .016$
Muscle coordination	1245	$+.06 \pm .018$

The closest relationship found with the "qualitative" nutritional condition was that for muscle tone and for skin color, the coefficients being +.70 and +.69 respectively. Somewhat less correlation was shown with the condition of the lungs, amount of subcutaneous tissue, posture, size of lymph glands of the neck, and tonsils, the coefficients ranging from +.55 to +.38. These values would indicate that both muscle tone and skin color are important factors in the evaluation of nutritional condition and that the other points mentioned above, while less significant, also contribute more or less to the picture. Some significance may also probably be attached to the color of the mucous membrane (lining of the mouth), though a value of but +.30 for *r* would indicate that it is not great. The coefficients obtained for bodily repose, heart, color of lips, conjunctivae, and muscle coordination are too low to indicate the existence of any significant correlation with status of nutrition.

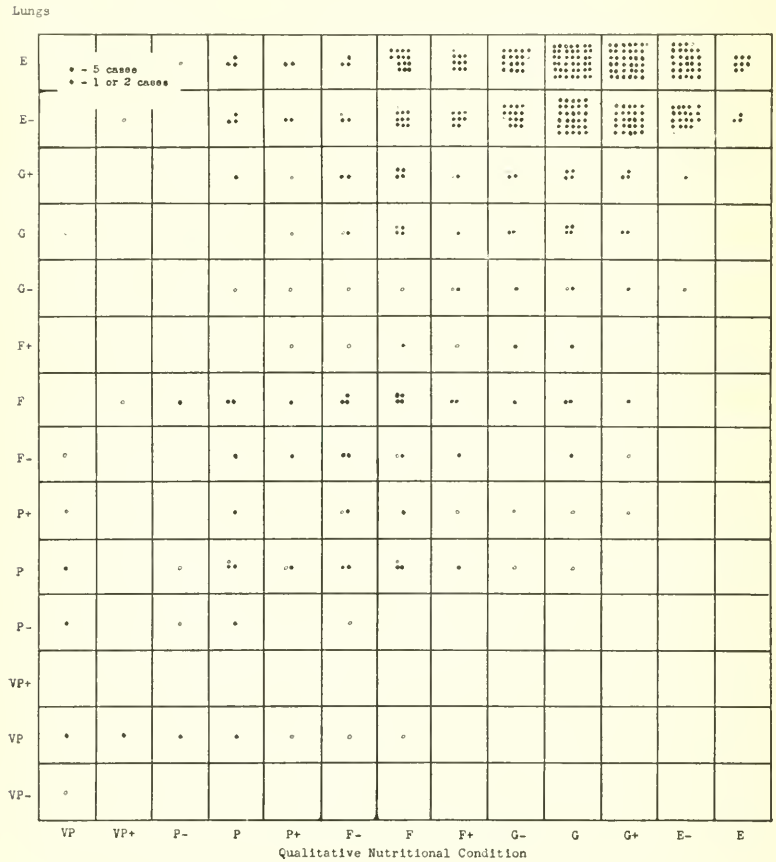

Chart 2. Correlation of the Condition of the Lungs with the "Qualitative" Nutritional Condition; showing that children may have normal lungs irrespective of their nutritional condition, but that children with poor lungs were rarely in good nutritional condition.

As would be inferred from such coefficients of correlation, the scatter in every case was wide, indicating that many factors are involved in the picture of an individual's nutritional condition even from a qualitative standpoint, and also that the observations made by the physician are affected by other influences as well as nutrition. Particular attention may be called to the relationships indicated for the condition of the lungs and tonsils and the amount of subcutaneous tissue with the nutrition ratings, which are shown graphically in Charts 2, 3, and 4.

The scatter plot (Chart 2) indicates that children might be rated from excellent to very poor nutritionally and at the same time have lungs in which no defects were found. But children whose lungs were in very poor or poor condition, for the most part also had other symptoms which marked them as poor from a nutritional standpoint.

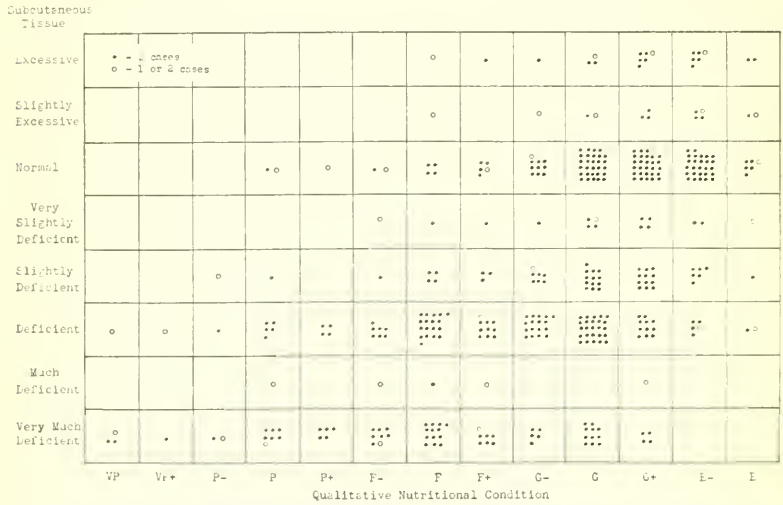

Chart 3. Correlation of Amount of Subcutaneous Tissue with "Qualitative" Nutritional Condition; showing that while the amount of subcutaneous tissue varied from very much deficient to excessive when the children were in good condition as indicated by a medical examination, it was almost invariably more or less deficient when they were in poor condition.

The scatter for amount of subcutaneous tissue (Chart 3) indicates that, while a child who had no clinical symptoms of malnutrition and was rated as good might have subcutaneous fat padding varying in amount from excessive to much deficient, those who were in poor condition almost without exception had little subcutaneous tissue.

The story of tonsils (Chart 4) was much the same. The child might show all other signs of being in good and even excellent condition and still have poor tonsils, but children in poor condition of nutrition did not have good tonsils and in most cases not even fair ones.

No attempt has been made to work out an objective scale for evaluating records of medical examinations, weighting the points observed on the basis of the amount of correlation found. Such an attempt did not seem justified at this time for several reasons. For one thing, because of inadequate descriptions, correlations

were not made for a number of observations which may be of importance. As a result no guide for weighting their influence was obtained. This refers to expression, and the condition of the hair, abdomen, skin, and nervous system in particular. It may be, too, that some better indication of the amount of hemogloben in the blood might be used than the color of the mucous lining of the mouth, although the latter was obviously somewhat better than lip color. Some observations which now seem important criteria on the basis of the experience of the study were not included in the examinations. For example, is not the quality of the subcutaneous tissue, its flabbiness or firmness, pertinent as well as the amount of fat padding? Then, how is one to describe that exuberance of well-being apparent in superb children, or the lack of it which is obvious in the appearance of other children but which may not be indicated clearly by the condition of the heart, lungs, tonsils, or even skin color? More careful work is needed before any rating scale which might be compiled for evaluating medical examinations may be expected to prove more satisfactory than estimations based on the careful judgment of a skilled observer.

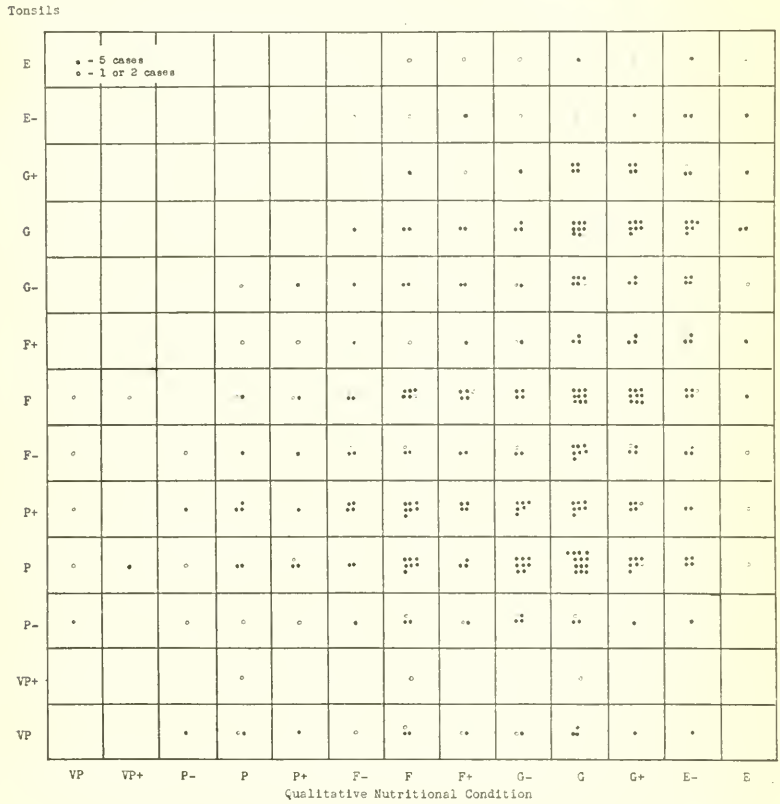

Chart 4. Correlation of the Condition of the Tonsils with "Qualitative" Nutritional Condition; showing that good tonsils were rarely found in children who were in poor nutritional condition, although poor tonsils might occur in children otherwise in good condition.

Accuracy of Medical Examinations

The accuracy of data in which the personal equation enters so largely as in medical examinations is always open to question. An attempt was made, therefore, to obtain some idea of the dependability of the records by observing the accuracy with which the physician would duplicate a number of examinations. Whether fortunately or unfortunately, a week or ten days was allowed to elapse between examinations. As a result the influence which colds and acute infections may have on the records is shown more clearly than the relative accuracy of the physician.

The conditions as given in the twenty-six duplicate examinations were correlated with those found in the original ones. With so few cases the coefficients obtained are significant only in indicating that in no instance did a high degree of agreement exist (Table 8). Further study of the two sets of records showed that practically every child had a cold at the time one examination was given or between the two or shortly before the first. Less correlation was indicated in conditions more apt to be influenced by acute illnesses as lungs and conjunctivae, or in those involving a change in color, which suggested that the lack of

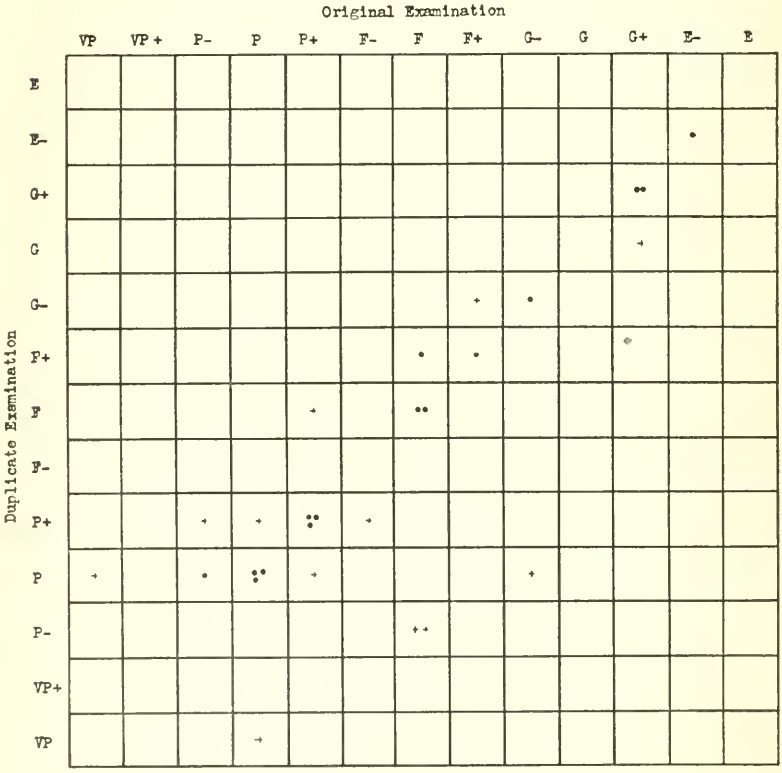

Chart 5. Correlation of the Condition of the Tonsils Found in 27 Duplicate Examinations with that in the Original.

☞ In most instances lack of agreement could be explained by colds, indicating that the physician's work was quite accurate. Crosses (+) indicate that the difference may be explained by a cold.

TABLE 8.—CORRELATIONS OF DUPLICATE WITH ORIGINAL EXAMINATIONS MADE ON TWENTY-SIX CHILDREN

1	Amount of subcutaneous tissue	+.87 ± .033
2	Heart	+.82 ± .043
3	Posture	+.81 ± .046
4	Tonsils	+.79 ± .049
5	Qualitative nutritional condition	+.75 ± .058
6	Glands	+.72 ± .057
7	Lungs	+.67 ± .071
8	Bodily repose	+.62 ± .082
9	Conjunctivae	+.60 ± 084
10	Muscle tone	+.52 ± 097
11	Color of lips	+.30 ± .120
12	Color of skin	+.27 ± .123
13	Color of mucous lining of mouth	+.21 ± .127

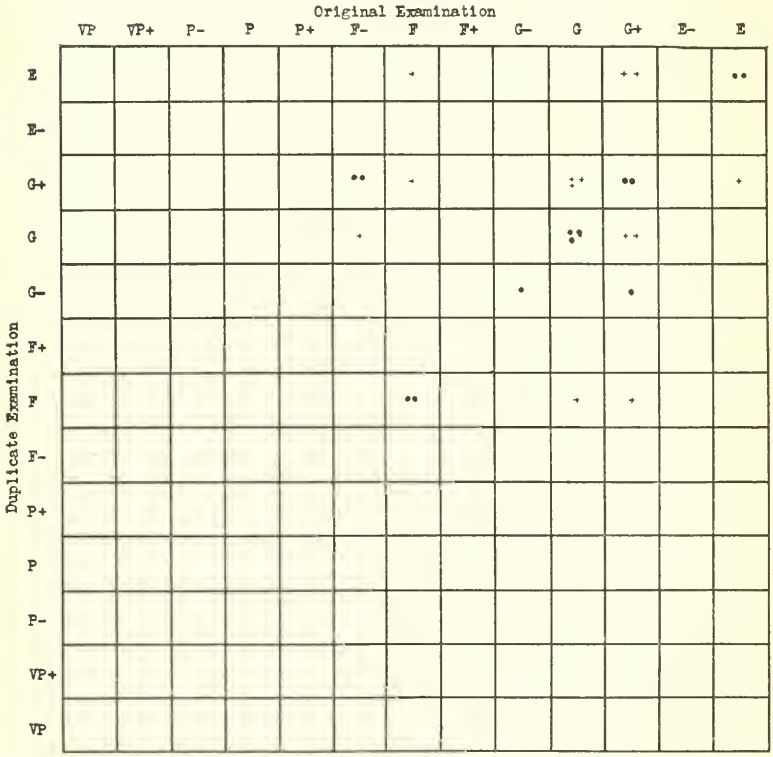

Chart 6. Correlation of the Skin Color Given in 26 Duplicate Examinations with that Given in the Original.

In a number of instances there were quite marked differences in the two examinations, and in three cases this could not be explained by a cold, which indicates the difficulty of grading color accurately. Crosses (+) indicate that the difference may have been due to a cold.

close agreement between the examinations might well be due to actual changes in the condition of the children because of colds, rather than to inaccurate work on the part of the physician. In confirmation of this it was found that, except when color was in question, in almost every case in which the difference between the two examinations was more than one step (for example from G to G−) it was in the direction which would easily be explained by the cold. In many cases a variation of one step could be explained in the same way. This is illustrated by Chart 5 in which the relationship of the condition of the tonsils as given in the two sets of examinations is depicted by a scatter plot. Crosses (+) indicate that the deviation could be explained by a cold. Scatter plots of other conditions observed give similar pictures. More unexplained discrepancies were found for the color of lips, mucous membrane, and skin, which raises the question of the dependability of observations in which changes of color are an index (Chart 6).

Change in Condition of Children Shown by Medical Examination

Tables 9 and 10 give the results of the medical examinations analyzed on the basis of percentages of children showing changes during the experimental period.

In Table 9 the results of the analysis for each point observed by the physician are compared. The experimental group as a whole was in better condition in June than they had been in September, but the control group was not. In the fed group 63 per cent had improved and only 14 per cent were in poorer condition at the end of the year; while but 33 per cent of the controls improved and 31 per cent were in poorer condition at the end of the same period. Improvement in posture, color of the mucous lining of the mouth, tonsils, and glands was also shown in a larger proportion of fed than control children. The difference was less marked in case of expression, hair, color of lips, lungs, heart, abdomen, skin, and muscle tone. For skin color, the eyes and ears as indicated by injection or inflammation of the conjunctiva and drums, amount of subcutaneous tissue, condition of the nervous system, and muscular coordination, the differences indicated, if any, are too small to be significant. In only one instance, bodily repose, are possible ill effects from the lunch suggested, and the differences between the control and experimental groups are too small to seem really significant.

Because of the effect of colds found when the duplicate examinations were compared with those made on the same children a few days previously, all examinations were discarded if made when the child had a cold or an acute infection of any nature, or if there was anything in the child's history which might explain conditions found or changes occurring since the preceding examination. This included recent colds and other acute illnesses as measles or whooping cough from which recovery was seemingly not complete; severe chronic infections which might have caused a loss in spite of the extra feeding; and the removal of tonsils during the year or in the previous summer, as the tonsillectomy might explain any improvement during the year. A few records were discarded because the father lost his job and the family was thrown into such straitened circumstances that the children received less and insufficient food at home.

After discarding all examinations in which causes other than the lunch were indicated for the changes observed, this analysis was repeated for those observations in which a significant correlation with nutritional condition had been found. The results are also given in Table 9. As before, the proportion whose general condition, posture, color of mucous membrane, tonsils, glands, and skin color improved was greater for the fed than for the control children. There was, however, no significant difference shown between the condition of the lungs

TABLE 9.—RELATIVE IMPROVEMENT FROM SEPTEMBER TO JUNE OF THE FED COMPARED WITH THE CONTROL CHILDREN, AS SHOWN BY THE PERCENTAGE IN WHOM CHANGES WERE NOTED IN VARIOUS CONDITIONS OBSERVED BY THE PHYSICIAN

Condition Observed	Children Receiving Mid-Morning Lunch				Children Receiving No Lunch—Controls				Relation of Experimental to Control Groups
	Total Number	Percentage			Total Number	Percentage			
		Better in June	Showing no Change	Poorer in June		Better in June	Showing no Change	Poorer in June	
All Examinations									
Nutritional Condition	703	63	23	14	311	33	36	31	Better
Posture	704	40	39	21	311	29	38	33	Better
Expression	346	10	81	9	155	8	75	17	Slightly better
Hair	705	25	67	8	310	20	74	6	Slightly better
Conjunctivae	703	23	53	24	311	22	46	30	Very slightly better
Ears (injection or infection)	703	7	87	6	311	7	88	5	No difference
Color of Lips	703	41	42	17	311	35	49	16	Slightly better
Color of Mucous Lining of Mouth	702	58	34	8	311	29	46	25	Better
Tonsils	495	45	17	38	225	25	13	61	Better
Glands	714	70	7	23	313	47	11	42	Better
Lungs	704	23	54	23	312	21	45	34	Slightly better
Heart	704	38	29	33	311	39	20	41	Slightly better
Abdomen	703	37	43	20	311	29	45	26	Better
Skin	684	25	54	21	310	26	46	28	Slightly better
Skin color	143	48	28	24	12	33	67	0	Question
Amount of Subcutaneous Tissue	695	24	53	23	311	20	57	23	Very slightly better
Nervous System	701	5	90	5	311	3	96	1	No difference
Muscular Coordination	560	48	30	22	286	47	29	24	No difference
Muscle Tone	704	22	69	9	311	15	78	7	Slightly better
Bodily Repose	704	32	55	13	308	34	58	8	Slightly poorer
After Discarding for Colds, etc.									
Nutritional condition	399	65	25	10	158	34	42	24	Decidedly better
Posture	399	42	40	18	158	30	39	31	Better
Color of Mucous Lining of Mouth	396	52	39	9	158	29	51	20	Better
Tonsils	275	45	18	37	112	27	11	62	Better
Glands	396	67	12	21	157	42	15	43	Better
Lungs	389	14	73	13	147	16	71	13	No difference
Skin Color	29	52	38	10	4	25	75	0	Better ?
Amount of Subcutaneous Tissue	370	24	55	21	153	22	62	16	No difference
Muscle Tone	398	21	68	11	158	16	79	5	No difference

of the fed and control groups after the influence of colds was eliminated. Changes in amount of subcutaneous tissue and in muscle tone do not seem significant. It may be that these last do not reflect the changes in nutrition quickly or that the methods of describing these conditions were too crude to indicate slight changes.

Further analysis of the numbers of children showing changes in nutritional condition as judged from the medical records is given in Table 10. After discarding for colds, etc., this shows a slight increase in the percentage who improved from September to June and a smaller percentage who were in poorer condition, which was largely due to the children receiving the evaporated milk. The most

TABLE 10.—PERCENTAGES OF CHILDREN WHOSE CONDITION AS SHOWN BY THE MEDICAL EXAMINATIONS CHANGED DURING THE EXPERIMENTAL PERIOD ACCOMPANYING A MID-MORNING SCHOOL FEEDING

Type of Mid-Morning Lunch	All Children				After Discarding for Colds, etc.			
	Total Number	Percentage			Total Number	Percentage		
		Better at End of Period	Showing no Change	Poorer at End of Period		Better at End of Period	Showing no Change	Poorer at End of Period
September to January								
Tomato Concentrate	111	38	44	18	97	36	43	21
Milk: Pasteurized	42	57	24	19	38	55	26	19
Milk: Evaporated	421	73	20	7	276	79	17	4
Milk: Evaporated plus Tomato	146	62	26	12	60	69	28	3
Milk: Total	609	70	21	9	374	74	20	6
All Receiving Lunch	720	65	25	10	471	67	25	8
No Lunch—Controls	284	27	41	32	162	30	44	26
January to June								
Tomato Concentrate	111	27	48	25	93	25	49	26
Milk: Pasteurized	42	43	26	31	40	45	28	27
Milk: Evaporated	399	25	48	27	239	26	55	19
Milk: Evaporated plus Tomato	131	37	32	31	51	35	43	22
Milk: Total	572	30	42	28	330	30	49	21
All Receiving Lunch	683	29	43	28	423	29	49	22
No Lunch—Controls	285	31	45	24	140	31	53	16
September to June								
Tomato Concentrate	113	36	40	24	103	37	40	23
Milk: Pasteurized	44	54	23	23	37	57	21	22
Milk: Evaporated	406	70	20	10	217	77	19	4
Milk: Evaporated plus Tomato	138	66	20	14	42	76	22	2
Milk: Total	588	68	20	12	296	74	20	6
All Receiving Lunch	701	63	23	14	399	65	25	10
No Lunch—Controls	285	33	35	32	158	34	42	24

striking effect of colds shown in this table is that, while the percentage who improved from January to June was shown to be the same whether the influence of colds was eliminated or not, the percentage whose condition became poorer during the same time was less after colds were discarded, indicating that part of the drop noted in the spring was due to these acute infections.

In the first analysis the findings had been the same as those from a similar analysis of changes in general nutritional condition; that is, during the fall a much larger proportion of the fed children improved than became worse, while the proportions in the control group were about the same. During the spring both groups just about maintained the January status with little or no relative improvement, so that the gains throughout the year apparent in the fed group were for the most part made in the fall. After discarding for colds a smaller percentage were in poorer condition at the end of spring.

When the groups receiving the different lunches are compared, the milk or the mixture of milk and tomato seem to have caused most changes. Only a slight difference in proportion of improvement is indicated in favor of the tomato over the controls. Again we hesitate to compare the effects of evaporated and pasteurized milk, as the findings for the latter are based on records made in the preliminary years of the investigation and on only a small group of children. It seems obvious, however, that milk, either pasteurized or evaporated, produced improvement in a larger percentage of children than tomato concentrate; and the tomato, in a slightly greater percentage than no lunch. No greater influence from a mixture of milk and tomato than from milk alone is indicated.

Change in Size of Glands

A decrease in the size and number of palpable glands seemed so obvious at the end of the first year that in the following years particular care was taken in describing them. The glands noted were the posterior and anterior cervicals, the submaxillary, submental, postauricular, suboccipital, axillary, and inguinal.

A score card was compiled in which 100 indicated no glands palpable. Of this total 48 were given to posterior cervicals, 24 to anterior cervicals, 10 to submaxillary, and less to the others which were palpable but occasionally. A definite amount was deducted when any gland was barely palpable, more if palpable, and still more if enlarged. The condition of the glands as described for each child at each examination was scored in this manner. The mean total scores as well as the scores for the posterior cervical, the anterior cervical, and the submaxillary glands are given in Table 11. Only the examinations remaining after discarding for colds and acute infections have been used. The mean total scores for all children were:

	Fed Group	Control Group
September score.....	77	77
January score.....	89	79
June score.....	87	77

That is, the mean score for the controls was the same at the beginning and at the end of the year, while that for the children who had received the feeding had increased 10 points or 13 per cent. In January and in June, the mean scores for the children receiving the mixture of milk and tomato were but 2 points higher than for those given milk. This difference does not seem enough to be significant.

The gland scores for six succeeding examinations at schools C and D are shown in Chart 7. The curve of the control school D drops from September 1930 to January 1931 and then slowly rises to a high point in January of the following year but drops again in June. The curve of the mean scores of school C, which had the feeding, rose during the first fall, was still high in June, but dropped almost to the original value in the following September. The high point was attained in the second January but was not maintained, though the score in June was higher than that in September.

Why the difference in the two year's records is not clear. All records in which there was indication of colds had been discarded. However, it is possible that a

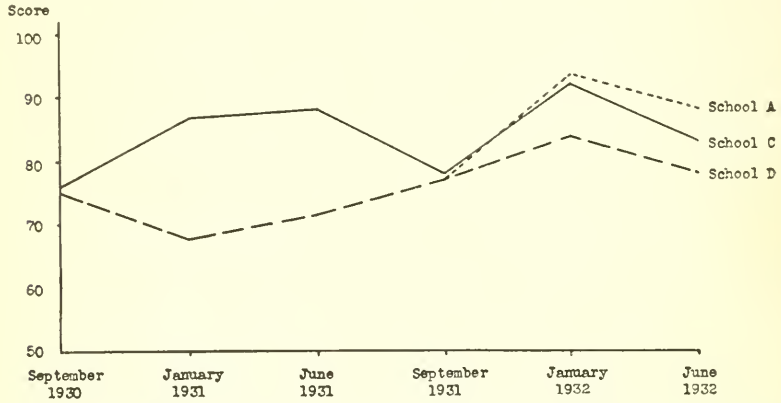

Chart 7. The Mean Total Gland Scores of the Children in School C (receiving evaporated milk) and School A (receiving evaporated milk and tomato) Compared with School D (controls).

severe epidemic of colds and "influenza" in school D during January and February 1931 and another in school C in February and March 1932 may be reflected in these scores. It is possible, too, that the economic stress which came with the partial closing of the mills in the spring of 1932, so that most of the mill workers were employed only part time, may have had some detrimental influence on the physical condition of the children. It did not prove possible to get sufficient data to determine whether this was actually true or not.

Had only one year's records been obtained in these two schools, an improvement as a result of the feeding would have been indicated, but the amount observed each year would have been quite different. When the two years are averaged together some of the variations are smoothed out. The two years' observations of the same groups also showed that the effects of the first year's feeding did not carry over the summer, for the score had dropped practically to the original by September. The posterior and anterior cervical glands were the ones most often found palpable. Most of the improvement indicated by the total gland scores was due to the smaller number and size of these glands palpable in the experimental children in January and June (Table 11). Much fluctuation was found in the scores for the submaxillary glands in all groups. These changes were not consistent and seemed to bear no relation to the feeding.

TABLE 11.—MEAN GLAND SCORES OF CHILDREN AS AFFECTED BY A MID-MORNING SCHOOL FEEDING*

School and Year	Number of Children			Total Gland Scores			Posterior Cervical			Anterior Cervical			Submaxillary		
	Sept.	Jan.	June	Sept.	Jan.	June	Sept.	Jan.	June	Sept.	Jan.	June	Sept.	Jan.	June
Evaporated Milk															
C 1930–31	146	155	145	76	87	88	34	39	41	16	21	21	9.0	10.0	9.4
C 1931–32	127	131	76	78	92	83	37	46	42	17	21	18	8.4	9.0	8.0
C Total	273	286	221	77	89	86	35	42	41	17	21	20	8.7	9.5	8.9
D 1932–33	21	30	36	82	88	87	42	44	43	17	19	18	7.7	8.7	8.5
Total	294	316	257	77	89	86	36	42	41	17	21	20	8.7	9.4	8.8
Evaporated Milk and Tomato															
A 1931–32	55	59	38	77	93	88	38	46	44	16	22	20	8.2	9.3	9.2
D 1932–33	11	16	19	81	90	88	40	46	42	17	20	19	8.1	9.1	9.1
Total	66	75	57	78	91	88	39	46	44	16	22	19	8.2	9.1	8.9
All Receiving Lunch															
Total	360	391	314	77	89	87	36	43	42	17	21	20	8.6	9.4	8.9
No Lunch—Controls															
D 1930–31	96	77	89	75	68	72	33	27	32	16	15	15	8.1	9.8	9.6
D 1931–32	73	63	52	77	84	78	37	40	38	16	19	16	8.0	8.0	7.9
D Total	169	140	141	76	75	74	35	33	34	16	17	15	8.1	9.0	9.0
Other Controls	27	37	32	83	93	87	40	46	42	18	22	21	9.2	9.5	8.9
Total	196	177	173	77	79	77	36	36	36	16	18	16	8.2	9.1	9.0

*After discarding for colds, all children receiving a fall examination used.

Summary

Before going on to a discussion of the effect of the mid-morning feeding on the growth of the children, the findings from a study of the medical records may be summarized as follows: definite though not marked improvement was indicated in the condition of the children receiving milk, whether pasteurized or evaporated, as a supplementary school feeding. Little if any effect of tomato juice in the amount given was shown in the condition of the children. The improvement was most evident in posture, color of mucous lining of the mouth, tonsils, glands, and skin color. None was apparent in the lungs, subcutaneous tissue, or muscle tone. Correlations indicate that a significant relationship existed between nutritional condition and muscle tone, skin color, lungs, subcutaneous tissue, posture, glands, tonsils, and color of mucous membrane, in the order given.

Influence of the Mid-Morning Lunch on Growth

All previous observers have reported that their subjects gained more rapidly in weight when given a supplementary school feeding. Leighton and Clark (11) also reported a definite increase in the growth of their subjects in height. In the present investigation the children who were given a lunch grew somewhat more rapidly than the controls in weight though not in height. The data on which this statement is based are summarized in Table 12.

TABLE 12.—WEEKLY GAINS OF CHILDREN IN WEIGHT AND HEIGHT AS AFFECTED BY A MID-MORNING LUNCH

Type of Mid-morning Lunch	Mean No. Weeks	Number of Children		Mean Gain in Height per Week				Mean Gain in Weight per Week			
		Boys	Girls	Boys		Girls		Boys		Girls	
				Cm	Per cent	Cm	Per cent	Kg	Per cent	Kg	Per cent
6-Year-Olds											
Tomato Concentrate	29.6	4	14	.10	.09	.10	.08	.05	.23	.05	.25
Pasteurized Milk	33.9	1	5	.11	.10	.10	.08	.03	.16	.03	.17
Evaporated Milk	35.1	36	37	.12	.10	.11	.10	.05	.21	.05	.22
Evaporated Milk and Tomato	36.1	4	2	.10	.09	.10	.09	.06	.29	.04	.23
All Receiving Lunch	34.1	45	58	.11	.10	.11	.09	.05	.25	.05	.23
No Lunch—Controls*	37.3	14	19	.11	.10	.11	.09	.06	.28	.06	.30
Difference				0	0	0	0	−.01	−.03	−.01	−.07
7-Year Olds											
Tomato Concentrate	29.3	7	5	.09	.07	.08	.07	.07	.28	.05	.20
Pasteurized Milk	33.9	2	2	.11	.14	.11	.10	.09	.40	.06	.27
Evaporated Milk	34.3	45	60	.11	.09	.11	.09	.04	.19	.05	.21
Evaporated Milk and Tomato	35.8	5	4	.10	.08	.10	.09	.07	.29	.05	.22
All Receiving Lunch	33.9	59	71	.11	.09	.10	.09	.05	.21	.05	.21
No Lunch—Controls	36.3	14	23	.10	.08	.10	.08	.04	.17	.06	.25
Difference				+.01	+.01	0	+.01	+.01	+.04	−.01	−.04
8-Year-Olds											
Tomato Concentrate	29.8	12	4	.08	.07	.10	.08	.05	.18	.07	.26
Pasteurized Milk	31.6	3	1	.09	.07	.09	.07	.08	.31	.06	.19
Evaporated Milk	32.8	46	36	.11	.09	.11	.09	.05	.19	.05	.18
Evaporated Milk and Tomato	36.2	13	17	.10	.08	.11	.08	.06	.26	.06	.24
All Receiving Lunch	33.2	74	58	.10	.08	.11	.08	.05	.21	.06	.20
No Lunch—Controls	33.8	20	24	.11	.09	.10	.08	.04	.17	.05	.19
Difference				−.01	−.01	+.01	0	+.01	+.04	+.01	+.01
9-Year-Olds											
Tomato Concentrate	29.5	10	3	.10	.07	.06	.04	.07	.25	.14	.46
Pasteurized Milk	31.3	2	2	.10	.08	.09	.07	.07	.24	.07	.24
Evaporated Milk	33.0	48	45	.10	.08	.11	.09	.05	.17	.06	.19
Evaporated Milk and Tomato	36.5	12	9	.10	.08	.11	.08	.06	.22	.07	.25
All Receiving Lunch	33.1	72	59	.10	.08	.10	.08	.05	.19	.06	.21
No Lunch—Controls	33.4	13	12	.10	.08	.12	.08	.05	.16	.04	.13
Difference				0	0	−.02	0	0	+.03	+.02	+.08
10-Year-Olds											
Tomato Concentrate	30.6	2	5	.06	.04	.10	.08	.07	.20	.13	.40
Pasteurized Milk	32.1	2	4	.10	.07	.08	.07	.07	.20	.03	.11
Evaporated Milk	32.2	18	18	.11	.08	.12	.10	.05	.17	.07	.24
Evaporated Milk and Tomato	35.6	17	10	.08	.06	.15	.11	.05	.18	.09	.28
All Receiving Lunch	33.3	39	37	.09	.07	.12	.09	.05	.17	.08	.26
No Lunch—Controls	32.5	11	15	.08	.06	.12	.10	.04	.15	.06	.18
Difference				+.01	+.01	0	−.01	+.01	+.02	+.02	+.08
11-Year-Olds											
Tomato Concentrate	30.1	7	4	.08	.06	.09	.07	.07	.20	.07	.19
Pasteurized Milk	31.7	3	5	.14	.07	.11	.07	.06	.20	.14	.35
Evaporated Milk	29.8	8	7	.10	.07	.13	.10	.04	.11	.08	.24
Evaporated Milk and Tomato	35.4	12	9	.10	.07	.13	.09	.06	.19	.11	.29
All Receiving Lunch	32.2	30	25	.09	.07	.12	.08	.06	.17	.10	.27
No Lunch—Controls	33.5	2	6	.11	.07	.12	.08	.04	.12	.05	.14
Difference				−.02	0	0	0	+.02	+.05	+.05	+.13
12-Year-Olds											
Tomato Concentrate	29.7	5	5	.09	.06	.08	.05	.10	.24	.14	.34
Pasteurized Milk	32.3	5	2	.11	.08	.12	.08	.05	.14	.11	.30
Evaporated Milk	30.1	1	4	.13	.09	.12	.08	.06	.16	.09	.25
Evaporated Milk and Tomato	34.0	4	7	.09	.06	.11	.07	.08	.19	.09	.22
All Receiving Lunch	31.8	15	18	.10	.07	.10	.07	.08	.19	.10	.27
No Lunch—Controls	33.4	6	6	.10	.07	.13	.09	.03	.10	.11	.29
Difference				0	0	−.03	−.02	+.05	+.09	−.01	−.02

*Does not include the first year at School D.

These findings are given in terms of the mean gains per week, actual and percentage, for boys and for girls at each age. The normal rate of growth of children is known to vary with sex and with age. Therefore, the experimental and control groups could not be compared as a whole. Because of the length of time required to obtain stripped weights of so large a number of children, the time elapsing between the first and last weighings varied more or less. The total gains have therefore been reduced to gains per week to make them comparable. In the first year in school D the fall weighings were not made until December or January. Both the total gains and weekly gains were lower in this group than in the same school the next year, probably because of the seasonal variations usually found in the growth of children. For this reason the records for the growth of the children in school D during 1930–31 have not been included in the summary. The rate of growth of children at any age varies more or less with their stature. To eliminate this variable, the weekly gains were calculated in terms of percentage of the fall weight or height.

As has already been stated, no influence of the feeding on gains in height is indicated either by the actual or percentage gains per week of the boys or of the girls. Greater gains in weight were found on the whole, however, in the fed children from six to twelve years of age. Numbers of older children were too few for a comparison to be significant. With the exception of the one receiving evaporated milk, the fed groups were not large, and the numbers at each age, therefore, were relatively small, which probably explains some of the fluctuations found. The mean gains of the evaporated milk group were more consistent and for the most part greater than gains observed in the controls. That these gains were less than those observed in the other fed groups may have been due in part at least to differences in stature. Children who are tall not only gain more but gain at a more rapid rate than short ones, and the majority of the children given evaporated milk were obviously shorter than children of the same ages in other groups.

To eliminate the possible racial factor, gains made in school D during the final year when a lunch was given were compared with those of the preceding year when the children were not fed (Table 13). With the exception of six-year-olds, the percentage gains per week were greater for the last year, and this improvement with the giving of a lunch was on the whole slightly more than that for all experimental children. The amount of this increase in gain in weight seems really somewhat surprising, as it varied from 10 to 50 per cent above that made by the controls. The difference in the six-year-olds is due not to less growth in the fed children at this age but to a relatively greater growth by the controls than was found at any other age. The explanation of this is not apparent.

It is quite generally thought that older children need extra feeding less than little ones, and therefore that supplementary feeding is more important for the lower grades. The results of this investigation do not confirm this popular belief. Age did not seem to have any influence on the proportion of children who improved, as shown by the medical examination, nor did the growth of the younger children appear to improve any more than that of the older ones. On the contrary, the greatest percentage increase in gains in weight was made by the twelve-year-old girls and the eleven- and twelve-year-old boys, while no improvement was evident in the six-year-olds.

TABLE 13.—WEEKLY GAINS OF CHILDREN IN SCHOOL D IN WEIGHT AND HEIGHT WHEN GIVEN MID-MORNING LUNCH AS COMPARED WITH NO LUNCH

Group	Number of Children		Mean Gain in Height per week				Mean Gain in Weight per week			
	Boys	Girls	Boys		Girls		Boys		Girls	
			Cm	Per cent	Cm	Per cent	Kg	Per cent	Kg	Per cent
5-Year-Olds										
Lunch	2	1	.13	.12	.13	.11	.04	.27	.04	.16
No Lunch	2	3	.10	.09	.10	.09	.03	.16	.04	.23
Difference			+.03	+.03	+.03	+.02	+.01	+.11	0	−.07
6-Year-Olds										
Lunch	9	11	.12	.10	.11	.10	.06	.27	.05	.26
No Lunch	12	12	.11	.10	.11	.09	.06	.29	.07	.32
Difference			+.01	0	0	+.01	0	−.02	−.02	−.06
7-Year-Olds										
Lunch	14	11	.12	.10	.11	.10	.05	.20	.05	.23
No Lunch	12	16	.10	.08	.09	.08	.04	.17	.05	.21
Difference			+.02	+.02	+.02	+.02	+.01	+.03	0	+.02
8-Year-Olds										
Lunch	12	13	.11	.09	.11	.08	.06	.23	.05	.17
No Lunch	17	19	.11	.09	.11	.08	.04	.16	.05	.18
Difference			0	0	0	0	+.02	+.07	0	−.01
9-Year-Olds										
Lunch	18	13	.10	.08	.11	.08	.05	.20	.05	.21
No Lunch	11	11	.11	.08	.12	.09	.05	.16	.04	.14
Difference			−.01	0	−.01	−.01	0	+.04	+.01	+.07
10-Year-Olds										
Lunch	13	8	.09	.07	.14	.11	.04	.14	.08	.28
No Lunch	7	9	.09	.07	.13	.10	.03	.11	.05	.15
Difference			0	0	+.01	+.01	+.01	+.03	+.03	+.13
11-Year-Olds										
Lunch	6	8	.09	.06	.13	.09	.04	.15	.11	.31
No Lunch	1	4	.09	.07	.10	.07	.02	.08	.03	.09
Difference			0	−.01	+.03	+.02	+.02	+.07	+.08	+.22
12-Year-Olds										
Lunch	0	3			.10	.07			.08	.24
No Lunch	3	2	.10	.07	.17	.13	.03	.09	.06	.22
Difference					−.07	−.06			+.02	+.02
13-Year-Olds										
Lunch	2	2	.12	.07	.15	.11	.06	.14	.11	.34
No Lunch	1	1	.15	.10	.19	.12	.10	.18	.04	.07
Difference			−.03	−.03	−.04	−.01	−.04	−.04	+.07	+.27

Influence of Feeding on School Attendance and Colds

The findings from an analysis of the records of school attendance are not conclusive. The mean number of days absent per child, whether for all causes or for illness, did not vary greatly for different groups in the same schools and was less than the variation between schools. The differences found between the whole groups receiving various lunches were also less than between groups in different schools receiving the same feeding. It was noticed, too, that there had been no epidemic other than ordinary colds throughout the year in the two communities in which the fewest absences were found, while in all the rest there

had been epidemics of "flu," measles, scarlet fever, or whooping cough, which in some instances were so general that schools were closed for a number of days. This being the case, it is not at all clear whether any of the differences found in school attendance were brought about by the lunches or whether they should be attributed to epidemics of acute infections or some other causes not so apparent.

The same may be said for the difference in the incidence and duration of colds in the various groups. Was it just chance or due to the feeding that the fewest days of colds came in a group which had no other epidemics during the winter, and that the total days of colds per child were the same from January to June in school D during the year in which they were given a lunch and the year when they had none? The findings show so many fluctuations and there are so many other possible causes of variation in the picture that any conclusion as to whether or not the lunches affected either the absences for illness or the incidence of colds does not seem warranted.

Influence of the Lunch on School Progress

An attempt was made to ascertain whether the lunches had any effect on the school progress of the children by comparing the total scores of the same mental achievement tests given in the fall and again about seven months later, in the spring. The findings from an analysis of these data do not give a clear picture.

During the year 1930–31 the Otis Group Intelligence Scale was used. For the first, second, and fifth grades the mean increase in the total scores for the May examination over those for the November examination was greater for the fed than for the control children. For the third and fourth grades the situation was reversed. For the whole group of 213 experimental children the mean increase was 6.3; for the 145 controls, 5.8 (Table 14). The difference does not seem significant. If there were any beneficial effects of the feeding, the tests given were too crude to detect them.

During the next two years the New Stanford Achievement Test was given to all but the first grades, which received the Pintner–Cunningham Primary Mental Test. Again the difference between the mean scores of the experimental and of the control groups in the first five grades as a whole was slight and was greatest for the first and second grades. The variations in the upper grades were less and fluctuated, sometimes in favor of the experimental group and sometimes in favor of the controls. For all those who received the advanced test (grades IV to VIII) the mean increase in total score was the same for the two groups, as indicated in the summary below. When all the children were considered, the mean increase in total scores was 10.8 for those who were given the lunch and 9.6 for those who received none, which is but little difference.

Mean Increase in Scores

Test	Grade	All Receiving Lunch	No Lunch-Controls
Pintner-Cunningham	I	11.2	8.1
New Stanford Achievement:			
Primary Test	II & III	13.9	12.5
Advanced Test	IV-VIII	7.4	7.2
Total		10.8	9.6

A large proportion of the experimental children were from foreign homes and started to school with a limited knowledge of English. The difficulty which some of the children had to even understand the directions given was a handicap, particularly in the first test. At the beginning of the second year some had not yet mastered the language so that they read as well as the English-speaking children, but at the end of the year the difference was less obvious. It is probable that the greater increase in the scores of the first- and second-grade children who received the lunches was in part due to the overcoming of the language difficulty of these foreign children. However, this does not appear to be the only explanation, since the mean increases in the scores for the first and second grades in school D during 1932–33 when they received a lunch were higher than those for the same grades in the same school the preceding year when the children received no feeding. It may be that these little folks were less fatigued and therefore able to apply themselves better as a result of the mid-morning lunch.

TABLE 14.—SCHOOL PROGRESS FROM OCTOBER TO MAY AS INDICATED BY THE MEAN INCREASE IN TOTAL SCORES FROM ACHIEVEMENT TESTS

Classified by School Grades					Classified by Mental Levels				
Grade	Experimental Group		Control Group		Range of I. Q.'s	Experimental Group		Control Group	
	Number	Mean Increase in Scores	Number	Mean Increase in Scores		Number	Mean Increase in Scores	Number	Mean Increase in Scores
					1930–31*				
I	39	13.0	29	7.5	130+	3	4.0	2	−7.0
II	56	11.0	40	7.0	110—129	61	11.7	44	6.4
III	53	3.1	42	5.7	90—109	120	6.6	81	6.4
IV	49	−0.5	22	2.7	70—89	58	5.2	18	3.2
V	16	5.4	12	4.0	50—69	1	−1.0	0	.....
Total	213	6.3	145	5.8	Total	243	7.1	145	5.8
					1931–32 and 1932–33†				
I	59	11.2	35	8.1	130+	16	10.6	3	11.5
II	87	15.6	44	12.9	110—129	108	11.2	43	9.5
III	88	10.6	33	11.8	90—109	143	11.0	76	9.9
IV	82	7.2	50	7.4	70—89	113	10.0	57	9.8
V	48	9.1	9	7.9	50—69	7	6.6	5	3.9
Total	364	11.3	171	9.8	Total	387	10.8	184	9.6

*Otis Group Intelligence scale used.
†Pintner-Cunningham mental test used for first, and New Stanford achievement tests for second to eighth grades.

It was possible that children at different mental levels might not react to the tests in the same manner, the brighter ones showing more improvement at the end of the year. The children were therefore divided into groups according to their I. Q.'s irrespective of age or grade. Some difference in the mean increase in total scores was found at most of the mental levels in favor of the experimental group, but was so slight, particularly when the achievement tests were used, as to be only suggestive. (Table 14.)

Influence of Feeding on Dental Caries

On first thought it might seem an easy matter to compare the incidence of caries during a period of time in two groups of children. It did not prove to be so simple, however, because of the changing number of teeth as the temporary ones are lost and the permanent are erupted; and because of the variation in the susceptibility to caries of different mouths and of different teeth in the same mouth.

By June most of the first-grade children had acquired their six-year molars and had begun to lose their temporary teeth; by ten years of age, the latter had all disappeared in the majority of cases, and the child had 24 permanent teeth unless he had been so unfortunate as to have had some extracted; and by twelve years, the second molars had begun to appear in many cases. The picture thus varied with the age of the children; and if temporary and permanent teeth were to be considered separately, it was necessary to make the comparison at each age. It was noted, however, that from six to twelve years inclusive there was but little variation in the total number of teeth per child, and also that the mean number of carious teeth was approximately the same irrespective of age. This analysis, therefore, has been made on the basis of the total number of teeth rather than on the basis of temporary and permanent teeth separately for children from five to twelve years of age.

Because of the loss of the temporary teeth, it was obvious that the difference between the number of caries found at the first and second examinations was not always an indication of the number which had developed in the interval between the two. To illustrate: B315 was found to have 9 carious teeth in September. In June he had but 8; but while he had lost 3 carious temporary teeth, new caries had developed in 2 other teeth. As a result his teeth were really in as poor condition in June as in September. A more logical approach, therefore, seemed to be to observe the number of teeth found at the June examination in which caries or pits and fissures had developed since the preceding fall, and to note whether any fewer had appeared in the fed than in the control children during the period of feeding.

That individual mouths vary in susceptibility to caries is a well-known fact, and whatever the cause, the disease seems to be more rampant in some groups than in others. It is also to be expected that fewer new caries will develop during the year in mouths which had the fewest at the beginning. A larger proportion of sound teeth was found among the Italian children of school C than among the other children. Accordingly the condition of each child's teeth was rated on the basis of the number of carious teeth found at the fall examination, as follows:

Percentage of Teeth Carious	Rating
0— 9	Excellent (E)
10— 29	Good (G)
30— 49	Fair (F)
50— 69	Poor (P)
70—100	Very Poor (VP)

The results of this analysis are given in Table 15. As was to be expected, the mean percentage of teeth in which new caries and new pits and fissures had appeared during the experimental period was lowest for those whose teeth were excellent at the beginning of the study. Between the experimental groups there

is no consistent difference in the incidence of new caries at the various levels of the condition of the teeth. The children who received both milk and tomato made no better showing than those receiving milk alone, nor is the slight difference between the experimental and control groups enough to be significant.

TABLE 15.—MEAN PERCENTAGE OF TEETH AT THE JUNE EXAMINATION IN WHICH CARIES OR PITS AND FISSURES HAD DEVELOPED SINCE THE SEPTEMBER EXAMINATION, AS AFFECTED BY MID-MORNING FEEDING

Condition of Teeth in September	Number of Children	Teeth per Child in June		
		Number	Percentage	
			With New Caries	With New Pits and Fissures
Evaporated Milk				
Excellent	36	27.1	3	2
Good	115	23.3	7	6
Fair	65	22.8	9	8
Poor	16	23.1	9	14
Very Poor	5	23.2	12	10
Total	237	23.7	7	6
Evaporated Milk and Tomato				
Excellent	14	26.0	5	7
Good	70	24.2	7	7
Fair	41	23.7	12	14
Poor	7	23.0	10	9
Very Poor	3	22.0	21	12
Total	135	24.1	9	10
All Receiving Lunch				
Excellent	50	26.8	4	4
Good	185	23.6	7	6
Fair	106	23.1	10	11
Poor	23	23.1	9	12
Very Poor	8	22.8	15	11
Total	372	23.9	8	8
No Lunch—Controls				
Excellent	27	24.4	10	7
Good	69	24.4	7	6
Fair	44	22.6	14	12
Poor	16	21.7	9	5
Very Poor	5	23.4	19	14
Total	161	23.6	10	8

Some observers (5) have contended that, as the teeth themselves vary in susceptibility, a more accurate statistical analysis may be made by comparing one type of teeth and that the first permanent or six-year molars are the best adapted for observation with children of this age. Such an analysis has been made and is summarized in Table 16. Again, beneficial effects of the feeding were not apparent. The same was true when the general condition of the teeth and gums (gingivae) was considered (Table 17). The percentage of children who showed improvement and the percentage who were in poorer condition at the end of the year were practically the same in the experimental and in the control groups.

No improvement in the condition of the teeth of children as a result of the mid-morning feeding either of evaporated milk or of evaporated milk and tomato is indicated by these data. It may be, of course, that the methods which it

seemed possible to use under the conditions of the study were not refined enough to detect improvements which may have occurred in some cases.

TABLE 16.—NUMBER OF SIX-YEAR MOLARS PER CHILD IN WHICH NEW CARIES AND PITS AND FISSURES HAD DEVELOPED BETWEEN THE SEPTEMBER AND JUNE EXAMINATIONS, AS AFFECTED BY THE MID-MORNING FEEDING

(Children 5 to 12 years, inclusive)

Condition of Teeth in September	Number of Children	Six-Year Molars per Child in June					
		Number	Number with New Caries	Number of New Caries	Number with New Pits and Fissures	Number of New Pits and Fissures	Number Extracted
Evaporated Milk							
Excellent	36	3.6	0.2	0.2	1.1	1.9	0
Good	115	3.8	.4	.6	1.3	2.2	0.1
Fair	65	3.9	.6	.8	1.5	2.9	.1
Poor	16	3.5	.5	.8	1.4	2.9	.1
Very Poor	5	3.2	.6	.8	1.4	2.6	0
Total	237	3.8	.4	.6	1.3	2.4	.09
Evaporated Milk and Tomato							
Excellent	14	3.7	.6	.8	.9	1.0	.1
Good	70	3.7	.6	.8	1.0	1.5	0
Fair	41	3.8	.9	1.1	.8	1.2	.2
Poor	7	3.0	.7	1.0	.9	1.3	.3
Very Poor	3	2.7	1.3	1.3	1.3	2.0	0
Total	135	3.7	.7	.9	.9	1.4	.08
All Receiving Lunch							
Excellent	50	3.6	.3	.4	1.1	1.6	.03
Good	185	3.8	.5	.7	1.2	1.9	.06
Fair	106	3.9	.7	.9	1.2	2.3	.14
Poor	23	3.3	.6	.9	1.2	2.4	.17
Very Poor	8	3.0	.9	1.0	1.4	2.4	0
Total	372	3.7	.5	.7	1.2	2.0	.09
No Lunch—Controls							
Excellent	27	3.4	.5	.6	.9	1.3	0
Good	69	3.9	.5	.6	1.4	2.1	0
Fair	44	3.8	.8	1.1	1.7	3.0	.1
Poor	16	3.6	.3	.5	1.4	3.1	.1
Very Poor	5	4.0	1.0	1.0	2.2	4.0	0
Total	161	3.8	.6	.7	1.4	2.4	.04

TABLE 17.—PERCENTAGE OF CHILDREN IN WHOM THE GENERAL CONDITION OF THE TEETH AND OF THE GUMS (GINGIVAE) CHANGED FROM SEPTEMBER TO JUNE

Type of Mid-Morning Lunch	Total Number of Children	Condition of Gums			General Condition of Teeth		
		Percentage of Children			Percentage of Children		
		Better in June	Showing no Change	Poorer in June	Better in June	Showing no Change	Poorer in June
Evaporated Milk	237	7	59	34	17	73	10
Evaporated Milk and Tomato	135	0	68	32	19	74	7
All Receiving Lunch	372	5	63	32	18	73	9
No Lunch—Controls	161	1	68	31	19	72	9

SUMMARY AND CONCLUSIONS

The effects of giving a mid-morning lunch to children have been studied in four rural elementary schools which involved some 760 children. The lunches consisted of pasteurized milk, reconstituted evaporated milk, tomato concentrate, and a mixture of evaporated milk and tomato juice.

A definite though not marked improvement in children seemed evident with the feeding of milk, whether pasteurized or evaporated, or a mixture of milk and tomato. This was evidenced by the greater proportion of children whose nutritional condition, as judged from the medical records, had improved from September to June, and by a more rapid rate of gain in weight, as well as by the improvement of the "general" nutritional condition of the children who received the feeding compared with those who had none.

The results obtained when evaporated milk was given seemed fully as great as when pasteurized milk was given.

Much less improvement was indicated with the feeding of tomato concentrate, though the difference would probably have been less had as much tomato as milk been given.

No increase in the rate of growth in height was found as the result of the feedings. The data as to the effect of the feeding on school absences due to illness and on the incidence and duration of colds were not conclusive.

Some favorable influence of the lunch on the school progress of the children of the lower grades was suggested, although the data were not entirely conclusive.

No significant evidence was found of a decrease in the incidence of dental caries as a result of the school feeding.

Improvement was noted in the children who were in good condition as well as in those who were in fair or poor condition at the beginning of the study. Age did not have any apparent influence on the amount of improvement shown by the medical records, but the greater percentage of increase in gain in weight was found in the older children.

That some improvement could be detected in the greater majority of the children as the result of giving but one cup of milk or even less of tomato juice as a mid-morning lunch, is a severe commentary on the home diets of the children. As there is no reason to think the dietary habits of the families in these communities were better or worse than those in many other villages, such findings justify the contention that the diets of the average family are very often more or less limited in some respects. Just what the limitations may be is not indicated, but in the communities studied they seemed to be corrected more effectively by milk than by tomato, though either or both improved the diets.

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